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A model to estimate the operating & maintenance (O & M) costs of the Mine Resistant Ambush Protected (MRAP) vehicles

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NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

A MODEL TO ESTIMATE THE OPERATING & MAINTENANCE (O&M) COSTS OF THE MINE RESISTANT AMBUSH PROTECTED (MRAP) VEHICLES

by

Tommy Chia

December 2010

Thesis Advisor:	Daniel A. Nussbaum
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13. ABSTRACT (maximum 200 words)

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This study analyzed the annual O&M costs of the MRAP vehicles, using available fiscal year (FY) 2008 and 2009 data from the MRAP Joint Program Office (JPO) and regression analysis. The regression models were subjected to tests of statistically significance and due to the shortage of data, were found to be insignificant. The O&M cost per vehicle for SOCOM was observed to be much higher than that of other services for most of the cost elements. There were, however, insufficient data to verify the factors that bring about the high cost. The importance of the observations lies in the following:

Problem	Recommendation
The paucity of the underlying dataset (FY 2008 and 2009 data) is the cause of the lack of statistical significance.	Continue to collect current annual O&M data for the MRAP vehicles by service, particularly SOCOM.
Army data representing 75% of MRAP inventory dominates the analyses.	Disaggregate data (when available) by service and develop service-unique models.

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A MODEL TO ESTIMATE THE OPERATING & MAINTENANCE (O&M) COSTS OF THE MINE RESISTANT AMBUSH PROTECTED (MRAP) VEHICLES

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Submitted in partial fulfillment of the
requirements for the degree of

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from the

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December 2010

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LIST OF ACRONYMS AND ABBREVIATIONS

ACAT	Acquisition Category
APC	Armored Personnel Carrier
CAIG	Cost Analysis Improvement Group
CAT	Category
CES	Cost Element Structure
CLS	Contractor Logistics Support
CONOPS	Concept of Operations
DASA-CE	Deputy Assistant Secretary of the Army for Cost and Economics
DoD	Department of Defense
FPII	Force Protection Industries Inc.
FSR	Field Service Representative
FY	Fiscal Year
GFE	Government Furnished Equipment
HMMWV	High Mobility Multipurpose Wheeled Vehicle
HST	Home Station Training
IED	Improvised Explosive Device
IDIQ	Indefinite Delivery Indefinite Quantity
JPO	Joint Program Office
JSSC	Joint Solutions Support Center
LRIP	Low Rate Initial Production
M-ATV	MRAP All Terrain Vehicle
MARCORSYSCOM	Marine Corps Systems Command
MILCON	Military Construction
MOE	Measure of Effectiveness

MRAP	Mine Resistant Ambush Protected
MSF	MRAP Sustainment Facility
NAVFAC	Naval Facilities Engineering Command
NCCA	Naval Center for Cost Analysis
NET	New Equipment Trainer
O&M	Operating and Maintenance
O&S	Operating and Support
OCO	Overseas Contingency Operations
OEM	Original Equipment Manufacturer
OSMIS	Operating and Support Management Information System
PLL	Prescribed Load Lists
POL	Petroleum, Oil and Lubricant
POM	Program Objective Memorandum
PPBES	Program Planning Budgeting Execution System
RCS	Radar Cross-Section
RDT&E	Research Development Test & Evaluation
RFP	Request for Proposal
RSA	Regional Support Activity
RWS	Remote Weapons Station
SME	Subject Matter Expert
SOCOM	Special Operation Command
SUV	Sport Utility Vehicle
TACOM	Tank Automotive Command
TMDE	Test, Measurement, and Diagnostic Equipment
ULSS	User's Logistics Support Summary
U.S.	United States
VAMOSC	Visibility & Management of Operation & Support Cost

EXECUTIVE SUMMARY

The role of High Mobility Multi-purpose Wheeled Vehicles (HMMWVs) in the United State military started in the late 1980s and their primary role was to transport personnel and cargo behind the front line. These vehicles were able to satisfy the needs of the U.S. military in conventional warfare, measured by acceptable personnel losses. The start of the War on Terrorism in 2001 brought about a rise in asymmetric warfare and low-intensity conflict, together with the employment of small arms fire, machine guns, rocket-propelled grenades and improvised explosive devices (IEDs) by the opposed side and along with it, the clear inability of the HMMWV's design to protect against these attacks.

As a result, in late 2007 the U.S. Department of Defense (DoD) launched a major procurement initiative with the intent to replace most of the HMMWVs with Mine Resistant Ambush Protected (MRAP) vehicles by the year 2009. These MRAP vehicles are known to have significantly higher personnel survivability in an IED or land mine encounter. This is due to the unique V-shaped hull design not seen in most armored personnel carriers (APCs) including the HMMWVs. In order to meet the large order and short fielding plan, many manufacturers were contracted with many variants of the MRAP vehicles produced. This implicitly translates to high downstream maintenance cost and logistics challenges.

This research was initiated due to a request from the Requirement and Acquisition Office (Policy Division) of the U.S. Special Operations Command (SOCOM) to understand the potential cost involved in the operating and maintenance (O&M) of their Mine Resistant Ambush Protected (MRAP) vehicles, which is presently funded under the Overseas Contingency Operations (OCO) budget request. This thesis develops a model to estimate the future O&M cost when funding from the OCO budget request ceases and is shifted to their service's budget.

The initial approach was to use the historical data residing in the Army's Operating and Support Management Information System (OSMIS) and the Marine Corps' Visibility and Management of Operating and Support Costs (VAMOSC) management information system as an analogy and then translate the result across to SOCOM. This direction proved to be infeasible because the relationship between the variables of the collected data (to-date) could not be correlated with reasonable statistical significance. As a last resort, the data source from the MRAP Joint Program Office (JPO), in the form of a cost element structure (CES), was used for the analyses.

This study analyzed the annual O&M costs of the MRAP vehicles, using available fiscal year (FY) 2008 and 2009 data from the MRAP Joint Program Office (JPO) and regression analysis. The regression models were subjected to tests of statistically significance and due to the shortage of data, were found to be insignificant. The O&M cost per vehicle for SOCOM was observed to be much higher than that of other services for most of the cost elements. There were, however, insufficient data to verify the factors that brought about the high cost. The importance of the observations lies in the following:

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I. INTRODUCTION

A. OBJECTIVE

This thesis investigates the cost involved in the operating & maintenance (O&M) of the Mine Resistant Ambush Protected (MRAP) vehicles in theater, in particular those under the inventory of the United States Special Operation Command (U.S. SOCOM), and thereafter, establishes a parametric relationship between this cost and the number of vehicles in the field. This relationship will assist the planners at the Requirement and Acquisition Office (Policy Division) of SOCOM to estimate the future sustainment requirements for these vehicles.

B. RESEARCH QUESTIONS

The following questions were generated to guide and scope the thesis.

1. Primary Research Question

- What parametric/statistical cost-estimating models (e.g., linear or non-linear regression) can explain and be used to predict the future maintenance cost of the MRAP vehicles under the inventory of SOCOM?

2. Secondary Research Questions

- How much does SOCOM spend annually on the running of the MRAP vehicles that are in their inventory?
- How does SOCOM's spending compare to that of the other services (e.g., Marine Corps) or other vehicles (similar function or class) within the service?
- How does this spending vary with the operational tempo in SOCOM?

C. BACKGROUND

Since the invasion of Panama by the United States (Operation Just Cause) in December 1989, the transportation of personnel and cargo behind the front line was

primarily through the use of High Mobility Multi-purpose Wheeled Vehicles (HMMWVs or Humvees) developed by AM General (a subsidiary of American Motors Corporation). Since then, these HMMWVs have been employed in numerous operations like Operation Desert Shield and Operation Desert Storm and have proven to be able to satisfy the needs of the U.S. military in conventional warfare. There were limited damages to the vehicles and acceptable personnel losses.

The rise of asymmetric warfare and low-intensity conflict, since the start of the War on Terrorism in 2001, brought about an additional requirement to the HMMWV's design, which is to defend against intense small arms fire, machine guns, rocket-propelled grenades and improvised explosive devices (IEDs). The HMMWVs were never designed with this feature in mind and subsequent modifications like additional armor was also unable to comply with this requirement. This brought about its dismay and created an urgent need for new vehicles with this protection. This eventually paved the way for the entry of the MRAP vehicles into the inventory of the U.S. military, especially for the Army and Marine Corps. The first MRAP vehicle initiated into the U.S. military was the "Buffalo," manufactured by Force Protection Industries Inc. (FPII), with the purpose of mine clearing. Since then, many requests and orders for MRAP vehicles were raised and processed; however, the importance of the mine protection vehicles in the war came on May 8, 2008, when the U.S. Secretary of Defense Robert Gates announced that "the acquisition of MRAP to be the highest priority of the Department of Defense."[1]

The traditional U.S. defense acquisition programs are funded through the Program Planning Budgeting Execution System[2] (PPBES) and Program Objective Memorandum[3] (POM) with short-term programs through the base DoD budget (Blakeman, Gibbs & Jeyasingam, 2008, p. 39). The funding of the MRAP vehicles, on the other hand, is

[1] A statement written in a memo addressed to the secretaries of the Army and Navy by the U.S. Defense Secretary Robert Gates in early May 2007.

[2] The PPBES process is an inclusive process that ties planning, programming, budgeting, and execution together to ensure activities the agency undertakes are effective in meeting the DoD's mission and vision.

[3] The POM document presents the proposed Army program to the Office of the Secretary of Defense. It presents planned activities and the personnel and obligation authority required over a five-year period to build, operate, and maintain this proposed program.

primarily done through supplemental appropriation and currently falls under the Overseas Contingency Operations (OCO) budget request. The intent of the OCO budget request (Office of the Under Secretary of Defense (Comptroller), 2009, p. 1) is to finance U.S. military operations around the globe in places such as Afghanistan, Iraq, and Pakistan. Areas of funding included under the OCO budget request are as follows:

- Continuing the Fight
    - Operations
    - Force Protection
    - Improvised Explosive Device Defeat
    - Military Intelligence
    - Afghan National Security Forces
    - Pakistan Counterinsurgency Capability Fund
    - Coalition Support
    - Commander’s Emergency Response Program
    - Military Construction
- Reconstituting the Force
    - Reconstitution

This research was initiated by the SOCOM to understand the potential operating and maintenance (O&M) cost involved in the running of their MRAP vehicles, which is presently funded under the OCO budget request. This thesis develops a model to estimate the future O&M cost when funding from the OCO budget request ceases and is shifted to their service’s budget. The study will assist the office in the requisition and allocation of funds for these vehicles or develop trade-off decisions.

D. METHODOLOGY

To facilitate the thesis research, data were requested from the Office of Deputy Assistant Secretary of the Army for Cost and Economics (DASA-CE); the Naval Center

for Cost Analysis (NCCA); and the MRAP Joint Program Office (JPO). From the first two sources the historical data on the operating & support (O&S) cost of the MRAP vehicles came directly from the Army's Operating and Support Management Information System (OSMIS) and the Marine Corps' VAMOSC management information system. From the latter, a summary was provided in terms of cost element structure (CES) of the MRAP program from fiscal year 2008 to 2013.

The next step is to apply various statistical analyses in an attempt to understand the behavior and determine a relationship between the different variables in the data. Finally, this thesis attempts to answer the research questions put forth at the start of this chapter. All the data analyses are performed using Microsoft Excel 2007 (Microsoft Corporation, 2006) and the data analysis tool residing in it.

E. THESIS ORGANIZATION

This thesis is divided into five chapters as follows:

- Chapter I presents the thesis objective; the primary and secondary research questions posted to guide the study; the background of the thesis research; and the methodologies used to conduct the research.
- Chapter II conducts a review of the literature and references related to the MRAP vehicles program in the U.S. military. The areas investigated are the vehicle design; the history; the setup of the program managing office; strategy of acquisition; the vehicle manufacturers; the vehicle classification; and the maintenance concept.
- Chapter III describes the data used for the analysis; that is those from Army's OSMIS, Marine Corps VAMOSC management information system and the MRAP JPO; and lastly why the data from the MRAP JPO was selected as most suitable for the analysis.
- Chapter IV shares with the reader the approach of the analysis, the measures of effectiveness (MOE) and the results. The results of the "best fit" relationship between the variables are displayed graphically with the achieved

MOEs. In addition, the chapter discusses the procurement trend and the cost of government furnished equipment (GFE) for each of the services.

- Chapter V concludes the thesis with the findings from the analyses by answering the research questions posted in Chapter I. It also talks about the usefulness of this information to SOCOM for their future MRAP vehicles sustainment estimation, and finally, identifies the prospect of future research.

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II. LITERATURE REVIEW

A. INTRODUCTION

This chapter provides: an explanation of the unique design used in all Mine Resistant Ambush Protected (MRAP) vehicles; a brief history of how MRAP vehicles came into the strength of the United States military; the managing team behind this Acquisition Category (ACAT) 1D-designated program; the aggressive acquisition process for this program; an overview of the manufacturers responsible for the many variants of MRAP vehicles; how the U.S. Department of Defense (DoD) classifies them; and finally, the present maintenance plan for these highly-utilized vehicles.

B. V-SHAPED HULL

The utilization of a V-shaped hull is the only commonality among all the different categories of MRAP vehicles from the many manufacturers. This ingenious V-shaped hull design is the reason behind the high rate of survivability of the personnel in the MRAP vehicles during an encounter with an adversary's land mines or improvised explosive devices (IEDs). A V-shaped hull refers specifically to the inclination of the floor plates to bulge towards the floor, creating what can be called a wedge. Attributed to the inclination of the hull (Figure 1), when a land mine or IED explodes there is no flat surface to act as a target for the blast. As a result, the main effect of the blast is directed outwards away from the vehicle instead of towards the bottom. This is because a path of least resistance, which leads most of the blast and shock waves away from the vehicle, is formed from the inclination of the floor plates.

Based on this reasoning, the more inclined the floor plates are, the higher the survivability rate of the personnel in the vehicle. There is a tradeoff though with the inclination angle, which is the need to maintain a minimum volume for housing the personnel and equipment, thus resulting in the overall height of the vehicle increasing. This may cause a problem for the stability, particularly prominent when turning at higher speeds. Another issue that comes about with a taller vehicle is the increase of the radar cross-section (RCS) signature of the vehicle, meaning easier detection by the enemy.

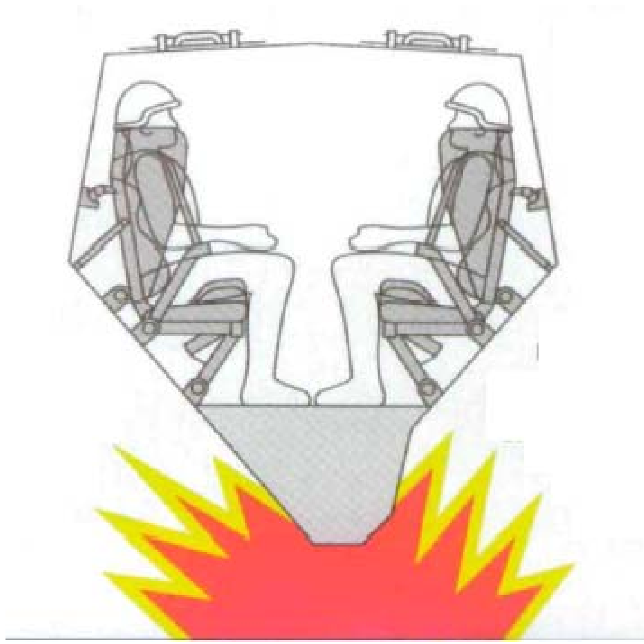

Figure 1. V-shaped Hull Design of the MRAP Vehicle (From Macabees, 2008)

C. HISTORY

The introduction of the "Buffel" armored personnel carrier (APC) into the arsenal of the South African Army in 1978 brought about a new and effective way of protection against land mines and later IEDs. It was in this vehicle that the V-shaped hull design was first employed. What started as a basic mine-protected vehicle went on to become a success with the South African Army, and eventually more than 1,400 units were delivered before production ceased.

For the U.S. military, the first MRAP vehicle that was initiated into their service was with the intent of mine clearing. This came about in September 2002 when the Army signed a contract with Force Protection Industries Inc. (FPII) to buy ten "Buffalo" at a value of US$6.5 million, with the delivery plan of two vehicles per year under a five-year contract. The effectiveness of the "Buffalo" MRAP vehicles against land mines and IEDs was quick to generate awareness in the U.S. DoD, with requests for them starting as early as 2003. Since then, many MRAP vehicle requests from the different services were raised. Due to budget constraints, it was only on November 9, 2006, that the first request for proposal (RFP) was issued to the industry to invite manufacturers to submit proposals

for the design. At around the same time as this RFP, in December 2006, the MRAP Joint Program Office (JPO) was established. Given the U.S. Marine Corps' lead in the program (Blakeman, Gibbs & Jeyasingam, 2008, p. 7), the JPO was setup within the Marine Corps Systems Command (MARCORSYSCOM), and Mr. Paul Mann was transferred from the Naval Sea Systems Command to serve as its first program manager. MRAP vehicles continue to generate awareness, and their importance came in May 2007 when Mr. Robert Gates, the U.S. Secretary of Defense, announced through the following memorandum that the acquisition of MRAP vehicles was the highest priority of the DoD[4]

> The MRAP program should be considered the highest priority Department of Defense acquisition program and any and all options to accelerate the production and fielding of this capability to the theater should be identified, assessed and applied where feasible. In this regard, I would like to know what funding, materiel, program, legal or other limits currently constrains the program and the options available to overcome them. This should include an examination of all applicable statutory authorities available to the Secretary of Defense or the President. (Owen, 2008, p. 14)

D. MRAP JOINT PROGRAM OFFICE

The MRAP Joint Program Office was established on December 6, 2006, to manage the acquisition, cost, and schedule of MRAP vehicles, with the mission statement as follows (MRAP Newsletter, 2010, p. 2):

> We deliver survivable, fully capable, Mine Resistant Ambush Protected (MRAP) Vehicles to our Warfighters and customers. We demand and support maximum readiness from our MRAP Vehicles once delivered. We operate with speed and a sense of urgency always.

The organizational structure with the current staffing is as shown in Figure 2 (Rodgers, 2010, p. 4). The office is staffed mainly by both military personnel and civilians from the Marine Corps and Army (indicated by a red- and green-colored outline respectively around the various appointments). In order to ensure that there is a subject matter expert (SME) from the other services in the JPO, liaisons appointments for SOCOM, the Navy and the Air Force are created.

[4] A statement written in a memo by the Defense Secretary Robert Gates addressed to secretaries of the Army and Navy early May 2007.

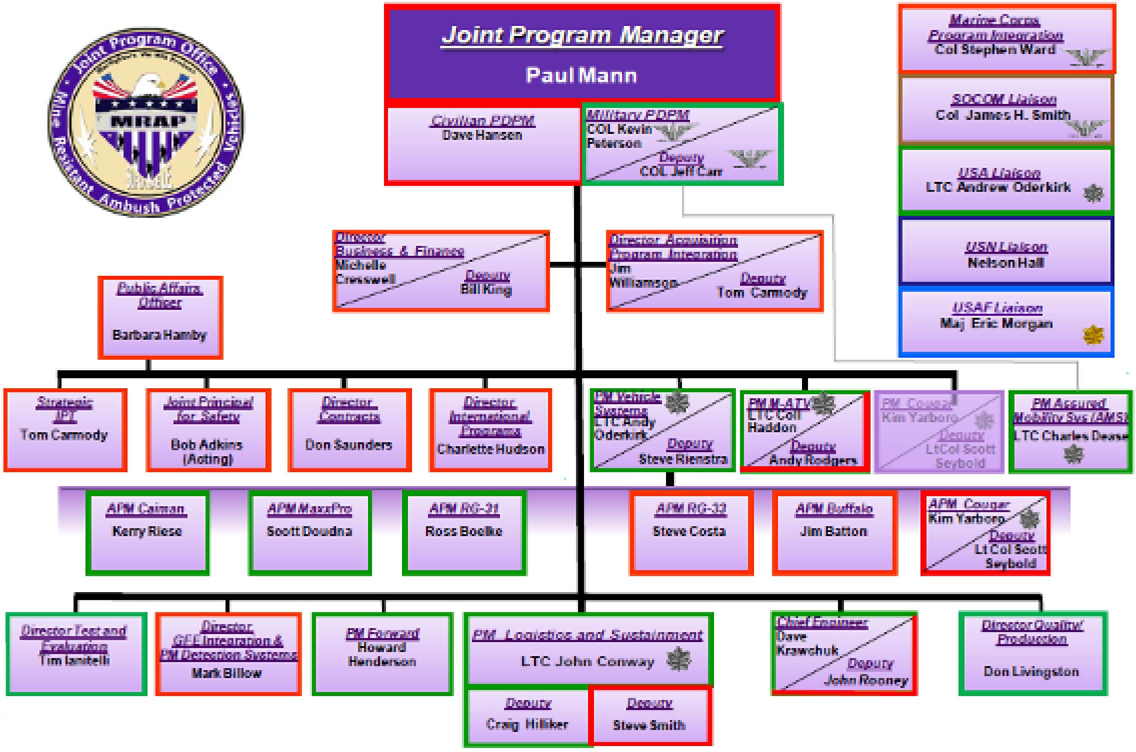

Figure 2. Organizational Chart of MRAP Joint Program Office (From Rodgers, 2010).

E. ACQUISITION STRATEGY

The acquisition strategy adopted at the onset by the JPO was to support three primary program objectives: "first, field survivable, mission capable vehicles; second, field them as rapidly as possible; and third, grow the industrial base while simultaneously managing all aspects of the acquisition process (Blakeman, Gibbs & Jeyasingam, 2008, p. 26)." This strategy was the key reason for the contracting of multiple manufacturers in the design and production of MRAP vehicles, leading to many variants in this program.

Unlike the traditional acquisition process which has more lead time and probably lesser quantity of units to produce, the MRAP program has neither. With the need to field these large orders as rapidly as possible, the approach was to first award a contract to a manufacturer with the capability at hand, in this case FPII, and simultaneously send out the RFP to the industry for more manufacturers to start producing these vehicles, thus enlarging the pool of suppliers in the long run.

This approach ensures unit production in the earliest possible timeframe. Designs from responding manufacturers were evaluated, and those that met the requirements were awarded with a low rate initial production (LRIP) contract. Risk assessment was then performed on the designs from the selected manufacturers and those deemed as “low risk” were instructed to start the production, concurrent to preparation for the development and user testing of their design. On the other hand, “high risk” manufacturers had to undergo the development and user testing prior to start of their production. Manufacturers who passed the testing phase were subsequently allowed to start production. Figure 3 shows the comparison in the acquisition strategy between the MRAP program and traditional ones.

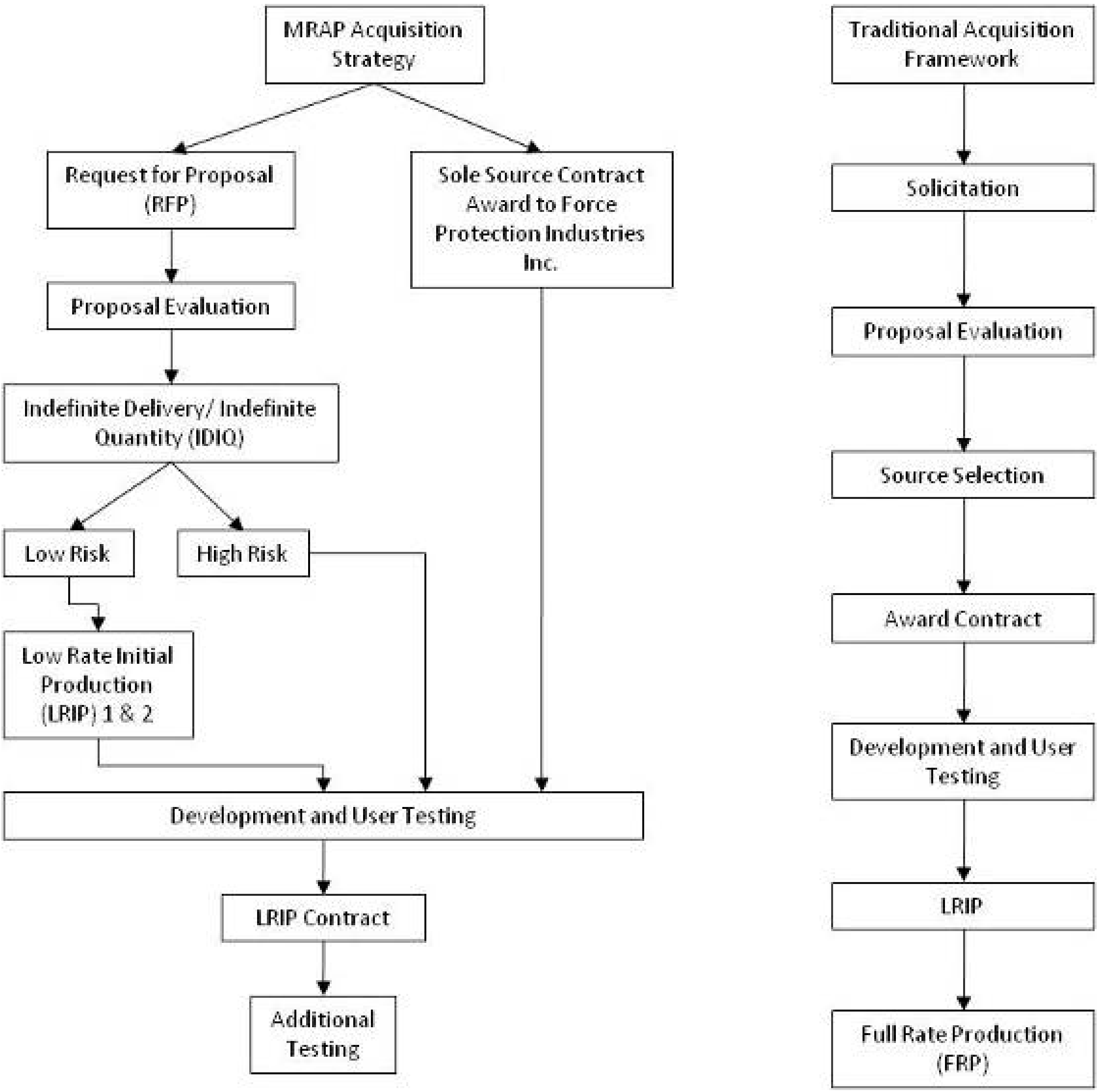

Figure 3. Comparisons of MRAP Acquisition and Traditional Acquisition Framework (From Blakeman, Gibbs & Jeyasingam, 2008, p. 29)

F. MANUFACTURERS

The issue of the RFP to the industry on November 9, 2006, resulted in nine manufacturers being awarded the "Indefinite Delivery Indefinite Quantity"[5] (IDIQ) contract on January 26, 2007. The IDIQ contract is comprised of two phases. The first phase involved the design and production of a small number of the manufacturer's design and subjecting these vehicles through a series of demonstration tests including survivability, automotive, safety and user testing. Once the first phase was cleared, the manufacturer was granted the "go-ahead" for the production of their design in a much larger order. Of the nine manufacturers, two were unable to deliver the vehicles within sixty days for phase one testing and another two failed to pass the survivability specifications. At the end of the first phase of the IDIQ contract, only the five following manufacturers were left:

- Armor Holdings Aerospace and Defense Group (Sealy, TX) (later acquired by BAE systems on July 31, 2007)
- BAE Systems (Santa Clara, CA)
- General Dynamics Land Systems – Canada (Ontario, Canada; manufactured in York, PA)
- Force Protection Industries, Inc. (Ladson, SC)
- International Military and Government LLC (Warrenville, IL) (now called Navistar Defense).

With these five manufacturers churning out the MRAP vehicles, the requirement for protection against land mines and IEDs was slowly met and a new add-on request started to surface—that is the need for higher mobility. On December 8, 2008, the U.S. Army Tank Automotive Command (TACOM) (Defense Update, 2009) issued another RFP for a fleet of new MRAP-class of vehicles with additional features of going off-road and the capability to go over rough terrain. Similarly, more than one manufacturer responded to the request. This time, the contract was awarded solely to the design from Oshkosh Defense on June 30, 2009. The initial number of vehicles of the MRAP All-Terrain Vehicle (M-ATV) for this contract (Defense Industry Daily, 2010) was 5,151

[5] IDIQ (Definition in Federal Acquisition Regulation Subpart 16.5)—a contract for supplies that does not procure or specify a firm quantity of supplies (other than a minimum or maximum quantity) and that provides for the issuance of orders for the delivery of supplies during the period of the contract.

units (apart from test vehicles)—2,598 for the Army, 1,565 for the Marine Corps, 643 for SOCOM, 280 for Air Force, and 65 for the Navy. With Oshkosh Defense added to the list, the present number of manufacturers for MRAP vehicles and their specialties is as shown in Table 1 (Global Security, 2010).

Manufacturer	Category I	Category II	Category III	M-ATV
Navistar Defense	- MaxxPro - MaxxPro MEAP Protected - MaxxPro Plus (EFP Protected) - MaxxPro Plus Ambulance - MaxxPro Dash	- MaxxPro XL		
BAE Systems/Global Tactical Systems	- Caiman/ XM1230 - Caiman Plus (EFP Protected)/ XM1230	- Caiman		
BAE Systems/Land Systems OMC	- RG-33 USSOCOM - RG-33 USSOCOM Plus	- RG-33L - RG-33L Plus (EFP Protected) - RG-33L HAGA - RG-33L HAGA Plus - RG-33L USSOCOM AUV		
Force Protection Industries	- Cougar A1 - Cougar A2 - Cougar HEV		- Buffalo A1 - Buffalo A2	
General Dynamics Land Systems/BAE Systems	- RG-31A1 - RG-31 Mk 5E/A2 - RG-31A3 (EM)			
Oshkosh Corporation				- M-ATV

Table 1. MRAP Vehicles Manufacturers

G. CLASSIFICATION

The many variants of MRAP vehicles supplied by the numerous manufacturers can be classified under the following four categories (Office of the Secretary of Defense, 2010, p. 2):

- Category I – used for small unit combat operations in urban or confined areas for missions such as mounted patrols and reconnaissance;
- Category II – used for convoy escort, combat engineering, ambulance, troop and cargo transportation;

- Category III – used to clear IEDs/mines and are the largest MRAP vehicles in terms of size; and
- MRAP All Terrain Vehicles (M-ATV) – a lighter vehicle for small unit combat operations in restricted, mountainous and urban terrain. It supports mounted patrols carrying up to five personnel.

H. MAINTENANCE CONCEPT

Due to the fast pace of the MRAP vehicles program with its primary goal of fielding the vehicles in the theater in the shortest time, the original sustainment plan was simply to rely on the contractor's logistics support (CLS) inclusive of parts and the field service representative (FSR). This sustainment plan proved to be successful with high operational readiness of the MRAP vehicles in theater. In 2007, with the large number of MRAP vehicles operating in the field and on order, the JPO decided that the initial intended sustainment plan was not economical and had to be changed to one which was organic to the unit, with the transition to take place immediately.

Since then, the maintenance plan for the MRAP vehicles program has been a mixture of organic maintenance operators and manufacturers' support, performed in three levels, namely tactical/unit, regional support activities (RSA) and the MRAP sustainment facility (MSF) (in ascending order of capabilities). This is graphically illustrated in Figure 4. At the tactical/ unit level, the organic maintainers are supported by the FSRs in the day-to-day corrective maintenance, in addition to the scheduled preventive maintenance at this level. The degree of involvement of the FSRs depends on the service and unit that they are attached to. It ranges from actual maintenance of the vehicles by the FSRs themselves to just providing expert advice or guidance to the organic maintenance operators in the attached unit.

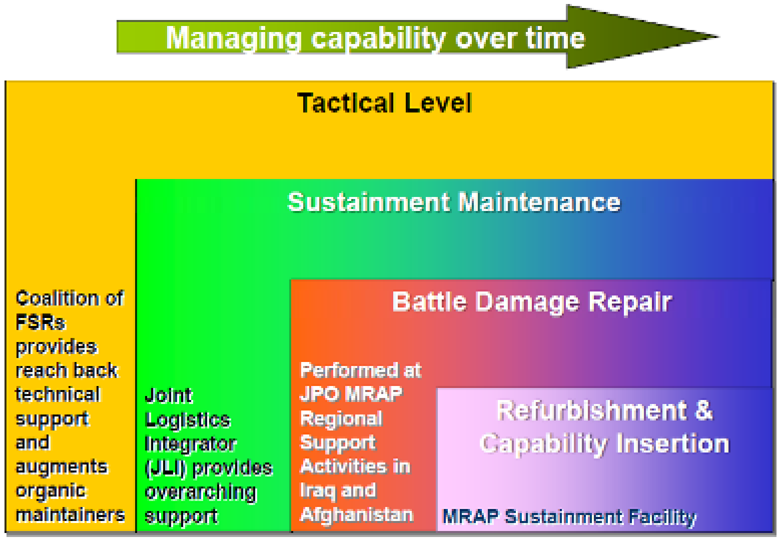

Figure 4. MRAP Vehicles Maintenance in Theater (From (Kulie, 2009, p. 3))

There are two RSAs for the maintenance of the MRAP vehicles theater, geographically located in Iraq (Figure 5) and Afghanistan (Figure 6). Both locations perform different functions for the program. In the Iraq RSA, it has the capabilities to carry out "responsible drawdown," namely "Scorpion Cascade for Home Station Training" (HST) and off-ramp equipment to Afghanistan; battle damage repair and sustainment maintenance; product improvements; and "sweep" the fleet. For the RSA in Afghanistan, it has the capabilities of fielding, sustainment, battle damage repair, facility infrastructure build-up, and a Joint Solutions Support Center (JSSC). The JSSC is a total package-fielding warehouse, so that prescribed load lists (PLLs) and parts to support fielding can be packaged.

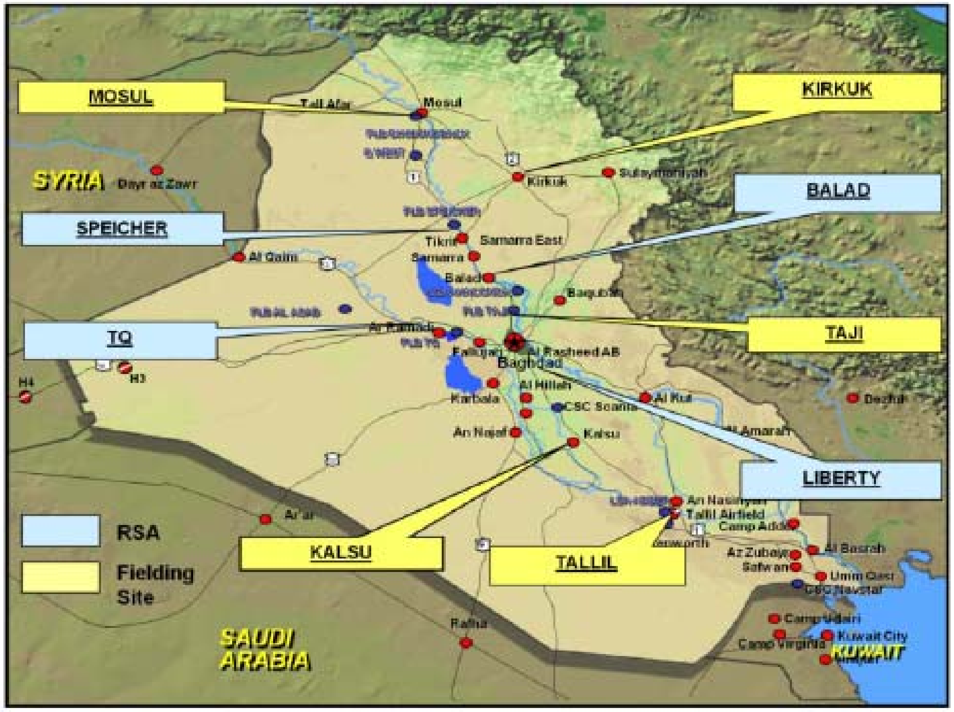

Figure 5. Regional Support Activities (RSA) in Iraq (From Kulie, 2009, p. 7)

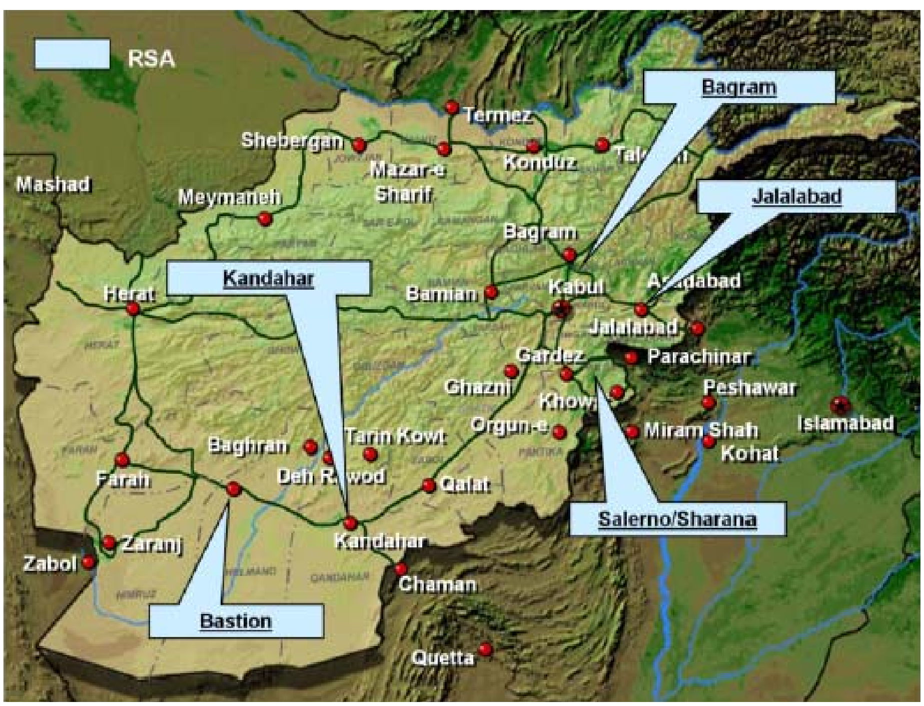

Figure 6. Regional Support Activities (RSA) in Afghanistan (From Kulie, 2009, p. 8)

The MRAP sustainment facility (MSF) is located in Kuwait (See Figure 7). Maintenance tasks that are beyond the ability of the RSAs are performed in this facility. The capabilities available in this facility include home station training, sustainment of theater vehicles stock, vehicle refurbishment, fleet training, unit fielding, capability insertion and independent suspension upgrades for FPII's Cougar MRAP vehicle. This facility is fully equipped since there has been continuous presence of U.S. forces in this country since the Persian Gulf War in 1991.

Table 2 shows the expected tasks to be performed and the capabilities at the operator, field and sustainment level extracted from the MRAP Vehicle user's logistics support summary (ULSS).

Figure 7. MRAP Sustainment Facility in Kuwait (From Kulie, 2009, p. 5)

Organizational (Operator Crew Level) Maintenance Capability
O-Level tasks consist of planned and/or corrective maintenance actions performed by the operating crews and will generally include: a) Preventive maintenance checks and services such as inspections, lubrication, cleaning, preserving, tightening, checking and topping off fluid levels, inspecting fittings and connectors, fuse replacement, and performing minor adjustments with common shop tools. b) Limited troubleshooting and repair. c) Monitoring and reporting system conditions. Maintenance at this level will be conducted on-site by crewmembers, whether deployed or at home base. Approximately 90 percent of all malfunctions will be detectable and correctable at the organizational level.
Intermediate (Field Level) Maintenance
I-Level is defined as maintenance tasks that are beyond the capability of the operating crews. Maintenance at this level will be performed by specially trained mechanics and technicians. Intermediate maintenance includes: a) Inspection/in-depth diagnosis, modification, replacement, adjustment, and limited repair or evacuation/disposal of principal end items and their selected repairable, components/subcomponents. b) Calibration and repair of test, measurement, and diagnostic equipment (TMDE), including fabrication of items, precision machining, and various methods of welding. Maintenance at this level will be conducted in a semi-protected environment on-site whether deployed or at home base.
Depot (Sustainment Level) Maintenance
D-Level maintenance tasks are to sustain equipment throughout its lifecycle by performing: a) Major repair, overhaul, or complete rebuild of parts, subassemblies, assemblies, or principal end items. b) Manufacturing parts and conducting required modifications, testing, calibrating, and reclaiming. c) Supports lower-level maintenance by providing overflow maintenance services and performing on-site maintenance services including technical assistance when required. Maintenance at this level requires a multi-commodity maintenance center, other services depots, commercial industrial facilities, OEMs, or a combination thereof to perform this level of maintenance.

Table 2. Maintenance Tasks at the Different Level (From Naval Facilities Engineering Command, 2008, p. 22)

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III. DATA SOURCES

A. INTRODUCTION

This chapter discusses the cost data of the Mine Resistant Ambush Protected (MRAP) vehicles that were used in the analysis. The initial approach to this thesis was to use the data from the records of the Visibility and Management of Operating and Support Costs (VAMOSC) management information system, since this is where the operating and support (O&S) cost data for the major systems in the United States military are stored. This direction proved to be infeasible as the relationship between the variables of the collected data (to-date) could not be correlated with reasonable statistical significance. The data that was finally used in the analysis came from the MRAP Joint Program Office (JPO).

This chapter is divided into two sections: the data from the Army's Operating and Support Management Information System (OSMIS) and the Marine Corps' VAMOSC management information system, and the data from the MRAP JPO.

B. DATA FROM ARMY OSMIS AND MARINE CORPS VAMOSC

The general term for the program of managing of the O&S cost in the U.S. military is known as VAMOSC management information system. It was started in 1975 and is presently handled by the respective services. Under the guidance of "DoD Cost Analysis Guidance and Procedures," (DoD 5000.4M) each service (Cheshire, 2003, p. 1) has developed a system based on the OSD Cost Analysis Improvement Group's (CAIG) cost element structure. For the Army, this data is managed with the use of the OSMIS under the Office of Deputy Assistant Secretary of the Army for Cost and Economics (DASA-CE). For Marine Corps, this responsibility belongs to the Naval Center for Cost Analysis (NCCA) and the center uses the Marine Corps VAMOSC management information system.

The approach to estimating the Special Operations Command (SOCOM) MRAP operating & maintenance (O&M) cost was to use the data from the Army and Marine Corps as analogies to SOCOM, and then translate it across, since SOCOM does not have

a VAMOSC management information system. This is considered a reasonable methodology, as the combined total number of MRAP vehicles in the Army and Marine Corps accounts for more than 80% of the whole fleet in the U.S. military. To begin the analysis, a set of historical data (shown in Appendix A) on the operating of MRAP vehicles in the Army and Marine Corps was obtained from both the OSMIS and the Marine Corps VAMOSC management information system. The idea was to find a relationship between the cost and the number of MRAP vehicles operated in the two services. The analyses on the scatter plots (Appendix B) of the data were that the variables cannot be linked in a statistically significant way. This finding effectively concludes that the current data in the OSMIS and the Marine Corps VAMOSC management information system on MRAP vehicles do not provide a reasonable baseline for use in future sustainment cost estimations of SOCOM. The "no pattern" behavior in the data from OSMIS and the Marine Corps VAMOSC management information system could be due to the problem in the data collection process, probably caused by the fast acquisition and fielding rates of the program. When the program matures and reaches a steady-state stage, it may be more worthwhile to perform another analysis based on the data from these systems. It is important to determine the exact cause of this behavior, since the database is the "backbone" for the estimation of future sustainment in the U.S. military.

C. DATA FROM MRAP JOINT PROGRAM OFFICE

A summary of the expenditures for the MRAP vehicles program was obtained from the MRAP JPO. This summary provides the previously spent and expected figures for research development test & evaluation (RDT&E) (CES 1.0); procurement (CES 2.0); military construction (MILCON) (CES 3.0); military personnel (CES 4.0); and operating & maintenance (CES 5.0) for fiscal years (FY) 2008 to 2013. The data from FY 2010 onwards was omitted from the analysis, since they are forecasts from the MRAP JPO.

This section provides a description of all the cost elements funded under operating & maintenance (CES 5.0), disregarding the rest of the cost elements since the questions to be answered are on the O&M cost of the MRAP vehicles.

There are fifteen different cost elements classified under the operating & maintenance (CES 5.0) element (Table 3), with their descriptions (MRAP JPO, PowerPoint presentation, 2010, slides 5–22) as follows:

- Field Maintenance (CES 5.1) – This element captures the cost of the in-theater field service representatives (FSRs). It is comprised of the manpower and personnel requirements to operate and maintain the MRAP vehicles.
- System Specific Base Ops (CES 5.2) – This element includes the cost to maintain the facilities supporting the MRAP vehicles in Iraq, Afghanistan, and Kuwait.
- Replenishment Spares (Reparables) (CES 5.3) – This element includes the costs of material used to repair the fleet of MRAP vehicles.
- Replenishment Repair Parts (Consumables) (CES 5.4) – This element includes the cost of material consumed in the maintenance and support of the fleet of MRAP vehicles.
- Petroleum, Oil & Lube (POL) (CES 5.5) – This element takes into account the cost of the petroleum, oil and lubricant consumed in the maintenance and support of the fleet of MRAP vehicles.
- Sustainment Overhauls (CES 5.6) – This element encompass the sustainment overhauls performed at the MRAP Sustainment Facility (MSF) and only on vehicles in theater.
- Transportation to/from Theater (CES 5.7) – This element includes the transportation of vehicles and parts to theater, and transportation of vehicles home from theater.
- Software (CES 5.8) – This element deals with the labor, material, and overhead costs incurred after deployment in supporting the update, maintenance and modification, integration and configuration management of software.
- System Test & Evaluation (CES 5.9) – The use of prototype, production, or specifically fabricated hardware/software to obtain or validate engineering data on the performance of the system during the development phase (normally funded from RDT&E) of the program. It also includes all effort associated with the design and production of models, specimens, fixtures, and instrumentation in support of the system level test program.
- Government/Contractor Program Management (CES 5.10) – This element includes the cost of the personnel who are supporting the MRAP JPO from both the government and contractor. Also included in this element are facilities and miscellaneous costs funded by the JPO.

- Training (CES 5.11) – This element includes all the costs for all of the training for the MRAP program. It includes the recurring cost of the MRAP University (that is facilities, supplies, tools, equipment and personnel), unique ambulance training, etc.
- Contractor Maintenance Support (CES 5.12) – This element is comprised of the cost involved in the in-theater contractor logistics support (CLS). It is only applicable to SOCOM.
- Lease Services & Equipment (CES 5.13) – This element contains all the cost associated with the leasing of services and equipment in theater for this program.
- Disposal/Demilitarization (CES 5.14) – This element includes the cost of disposing and demilitarization of the in-theater MRAP vehicles.
- Other Matters (CES 5.15) – This element is comprised of that which is not covered under the above cost elements. It includes storage, transportation to storage, data manuals, etc.

From Table 3, there are two obvious observations. First, some of the cost elements do not incur spending for the period of FY 2008 and FY 2009. This means that the funding for these cost elements has either passed or yet to come. As a result, there is no way of understanding or analyzing these cost elements. Secondly, “Transportation to Theater” (CES 5.7.1) is the only cost incurred for the MRAP vehicles program in FY 2008. With the absence of funding for the rest of the cost elements in FY 2008, it can be deduced that this is the year in which all (if not most) of the MRAP vehicles from the various services were transported to theater. Thus, going forward the analysis in the following chapter will only utilize the O&M data from FY 2009.

		USMC		Army		Navy		Air Force		SOCOM	
CES	**Element**	**FY08**	**FY09**	**FY08**	**FY09**	**FY08**	**FY09**	**FY08**	**FY09**	**FY08**	**FY09**
5.0	**O&M Funded Elements**	**$425,281**	**$357,188**	**$487,000**	**$1,223,114**	**$17,985**	**$56,937**	**$12,947**	**$77,862**	**$56,951**	**$149,321**
5.1	Field Maintenance Civilian/Contractor Labor Below Sustainment	$0	$39,500	$0	$199,000	$0	$6,000	$0	$14,300	$0	$18,182
5.2	System Specific Base Ops	$0	$7,981	$0	$31,036	$0	$1,274	$0	$1,576	$0	$2,176
5.3	Replenishment Spares (Reparables)	$0	$35,000	$0	$200,000	$0	$10,242	$0	$10,153	$0	$21,130
5.4	Replenishment Repair Parts (Consumables)	$0	$40,000	$0	$270,000	$0	$14,625	$0	$14,499	$0	$30,175
5.5	Petroleum, Oil & Lube (POL)	$0	$6,807	$0	$31,832	$0	$1,456	$0	$1,420	$0	$1,246
5.6	Sustainment Overhauls	$0	$51,269	$0	$100,000	$0	$10,898	$0	$11,034	$0	$19,978
5.7.1	Transportation to Theater	$135,745	$82,000	$487,000	$240,000	$17,985	$3,426	$12,947	$10,301	$56,951	$8,000
5.7.2	Transportation from Theater	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.8	Software	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.9	System Test & Evaluation	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.10.1	Government Program Management	$0	$37,000	$0	$25,000	$0	$491	$0	$1,985	$0	$2,000
5.10.2	Development Contractor Program Management	$0	$21,757	$0	$0	$0	$3,474	$0	$4,296	$0	$5,933
5.11	Training	$0	$29,503	$0	$99,124	$0	$3,880	$0	$7,000	$0	$10,000
5.12	Contractor Maintenance & Support	$0	$0	$0	$0	$0	$0	$0	$0	$0	$29,000
5.13	Leased Services & Equipment	$0	$834	$0	$3,242	$0	$133	$0	$165	$0	$227
5.14	Disposal/ Demilitarization	$0	$2,758	$0	$13,071	$0	$594	$0	$586	$0	$516
5.15.1	Storage	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.15.2	Maintenance	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.15.3	Transportation to Storage	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.15.4	Data Manuals	$0	$2,779	$0	$10,808	$0	$444	$0	$549	$0	$758

Table 3. O&M-Funded Elements for All the Services

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IV. DATA ANALYSIS

A. INTRODUCTION

This chapter describes the analytical approach, the qualification criteria and the results of the regression analysis performed on the fifteen cost elements under the operating & maintenance (CES 5.0) funded elements for FY 2009 cost data from the Mine Resistant Ambush Protected (MRAP) Joint Program Office (JPO). In addition, it looks at the procurement trend of the MRAP vehicles by examining the low rate initial production (LRIP) procurement prices for the period of FY 2007 to 2008 and discusses the cost of government furnished equipment (GFE) among the services for the data from FY 2008.

B. REGRESSION ANALYSIS

1. Method

The first step in the regression analysis is to determine the type of relationship (linear, non-linear, quadratic) between each cost element (dependent variable) and the number of MRAP vehicles in operation (independent variable). This is done simply by visual inspection of the scatter plot of the dependent variable versus the independent variable. Then, once a relationship has been identified, the mathematical function (e.g., linear) linking the dependent and independent variables is subjected to a series of statistical examinations to evaluate the strength of this relationship. If the function does not meet the passing criterions of the statistical examinations, another function (e.g., non-linear) is devised. The process continues until the passing criterions for the statistical examinations are met or there is no more improvement. At this stage, the “best fit” function between the variables is found.

2. Measures of Effectiveness

In order to statistically “accept” a selected mathematical function and consider it to be suitable for representing the relationship between the cost

element and the number of vehicles, a set of passing criteria or measures of effectiveness (MOE) have to be established. For this analysis, the following are employed:

- F-test – this indicates whether the mathematical function is preferred to the mean of the dependent variable. That is, whether the coefficients of all the independent variables are zero (Nussbaum, PowerPoint presentation, 2009, slide 24). A p-value of less than 0.05 is desired.
- t-test – this test is used to assess the strength of the relationship between the dependent variable and independent variables at a given level of significance. A p-value of less than 0.05 is desired.
- Coefficient of Determination (R^2) – this is used in the context of statistical models where the main purpose is the prediction of future outcomes on the basis of other related information. It is the proportion of variability in a data set that is accounted for by the statistical model. It provides a measure of how well future outcomes are likely to be predicted by the model. The desired value is set to be greater than 0.9 (Steel & Torrie, 1960, pp. 187, 287).
- Adjusted Coefficient of Determination (adj R^2) – this is a modification of the R^2 that adjusts for the number of explanatory terms in the model. Unlike R^2, the adjusted R^2 increases only if the new term improves the model more than would be expected by chance. The adjusted R^2 can be negative and will always be less than or equal to R^2. The desired value is set to be greater than 0.9 (Benchimol, 2008, p. 2).

3. Results

For the regression analysis, a series of mathematical functions were fitted to the relationship between each of the cost elements (dependent variable) and the number of operated vehicles (independent variable), and the results of the "best fit" function (details in Appendix C) are shown as follows:

- CES 5.1 Field Maintenance (as shown in Figure 8)
  - Best fitted relationship – linear
  - p-value of F-test = 7.440E-5
  - p-value of t-test (independent variable) = 7.440E-5
  - p-value of t-test (intercept) = 0.222
  - Coefficient of determination (R^2) = 0.997

- Adjusted coefficient of Determination (adj R^2) = 0.996
- Function: y = 4402965.4 + 14681.1 x

Inference: There is an apparent linear relationship between the cost incurred in "Field Maintenance" and the number of operated MRAP vehicles. Due to the paucity of the underlying data used in the analysis, the regression line is not statistically significant. The high p-value of the t-test (intercept) and the wide confidence interval (-4.7 to 13.5 million, highlighted in Table 9) confirmed the finding. The number of MRAPs alone is not a good variable for estimating the cost for this element.

Observation: The prediction error of this function is approximately 50% for SOCOM in FY 2009, while it is less than 5% for the Army and the Marine Corps.

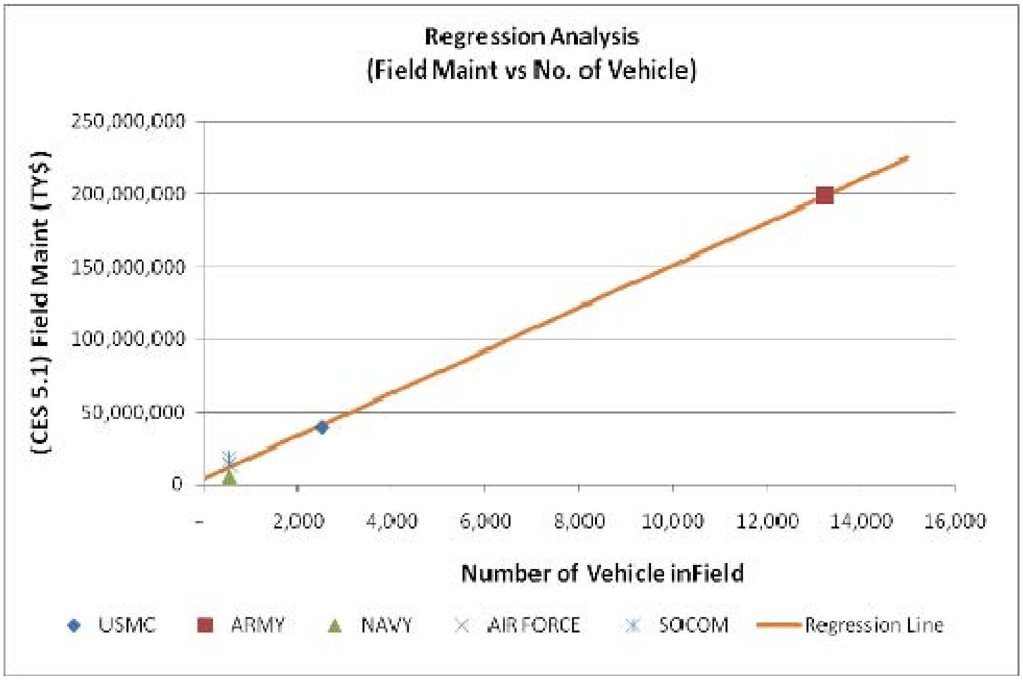

Figure 8. Regression Analysis for CES 5.1 Field Maintenance (FY09)

- CES 5.2 System Specific Base Ops (as shown in Figure 9)
    - Best fitted relationship – linear
    - p-value of F-test = 1.241E-4
    - p-value of t-test (independent variable) = 1.241E-4
    - p-value of t-test (intercept) = 0.220
    - Coefficient of determination (R^2) = 0.996
    - Adjusted coefficient of determination (adj R^2) = 0.994
    - Function: y = 823913.5 + 2298.8 x

Inference: The regression model between the cost incurred in "System Specific Base Ops" and the number of operated MRAP vehicles appears to be linear and can be misleading. The high p-value of the t-test (intercept) and the confidence interval (-0.9 to 2.5 million, highlighted in Table 10) reveal that the best-fitted function is not statistically significant. Therefore, the number of MRAPs alone is not a good variable for estimating the cost for this element.

Observation: For this cost element, the prediction error obtained for SOCOM is about 6%.

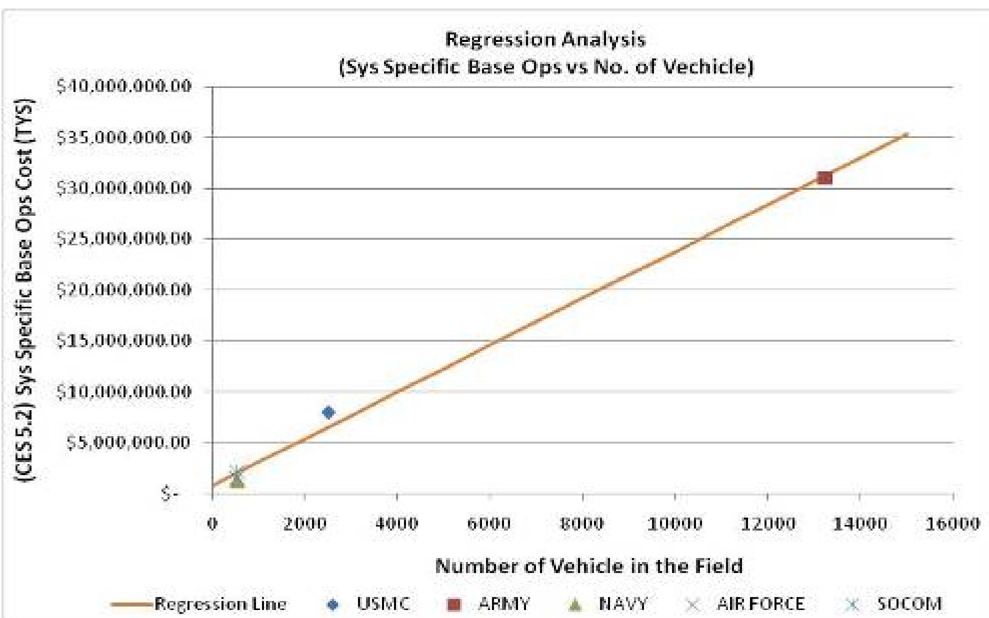

Figure 9. Regression Analysis for CES 5.2 System Specific Base Ops (FY09)

- CES 5.3 Replenishment Spares (Reparables) (as shown in Figure 10)
    - Best fitted relationship – linear
    - p-value of F-test = 7.440E-5
    - p-value of t-test (independent variable) = 7.440E-5
    - p-value of t-test (intercept) = 0.222
    - Coefficient of determination (R^2) = 0.997
    - Adjusted coefficient of determination (adj R^2) = 0.996
    - Function: y = 4163806.1 + 14723.6 x

  Inference: The apparent relationship between the cost incurred in "Replenishment Spares (Reparables)" and the number of operated MRAP vehicles is linear. Due to the paucity of the underlying data used in the analysis, the regression line is not statistically significant. The p-value of the t-test (intercept) and the confidence interval (-4.7 to 13.5 million, highlighted in Table 11) substantiate this result. The number of MRAPs alone is not a good variable for estimating the cost for this element.

  Observation: An error of about 75% is seen when using this function for the cost estimation for SOCOM in FY 2009, while it is less than 1% for the Army.

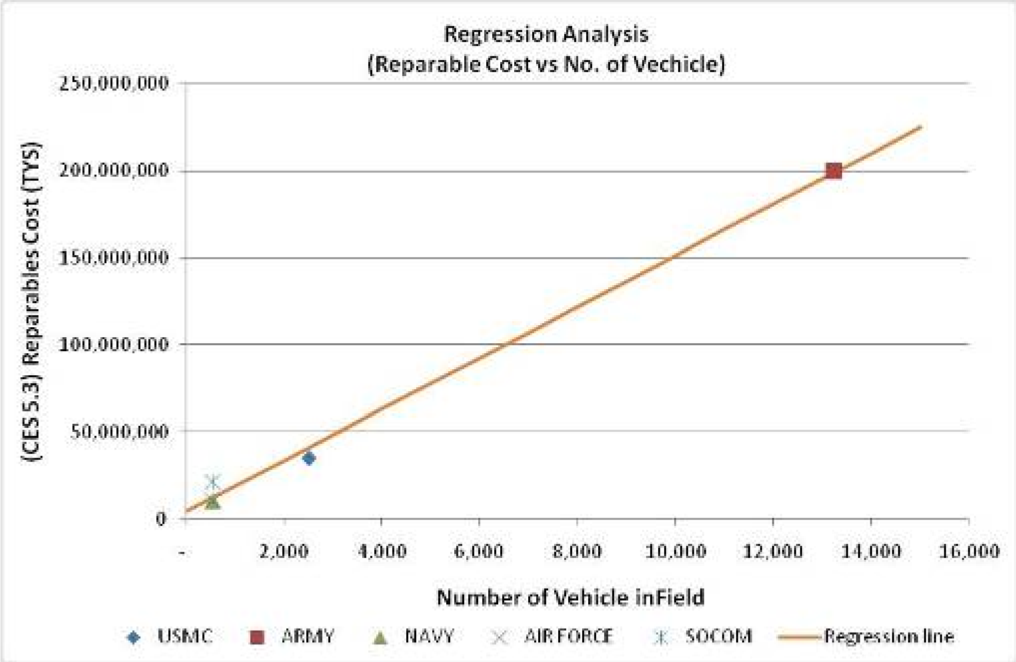

Figure 10. Regression Analysis for CES 5.3 Reparable (FY09)

- CES 5.4 Replenishment Repair Parts (Consumable) (as shown in Figure 11)
  - Best fitted relationship – linear
  - p-value of F-test = 3.650E-4
  - p-value of t-test (independent variable) = 3.650E-4
  - p-value of t-test (intercept) = 0.513
  - Coefficient of determination (R^2) = 0.991
  - Adjusted coefficient of determination (adj R^2) = 0.988
  - Function: y = 4891670.5 + 19856.1 x

  Inference: Similarly, the apparent relationship between the cost incurred in "Replenishment Repair Parts (Consumable)" and the number of operated MRAP vehicles is linear. The p-value of the t-test (intercept) and the confidence interval (-16.1 to 25.9 million, highlighted in Table 12) are indicative that the regression model is not statistically significant. The number of MRAPs alone is not a good variable for estimating the cost for this element.

Observation: The prediction error of this function is almost double when used on the FY 2009 data for SOCOM, while it is less than 7% for the Air Force, Navy, and Army.

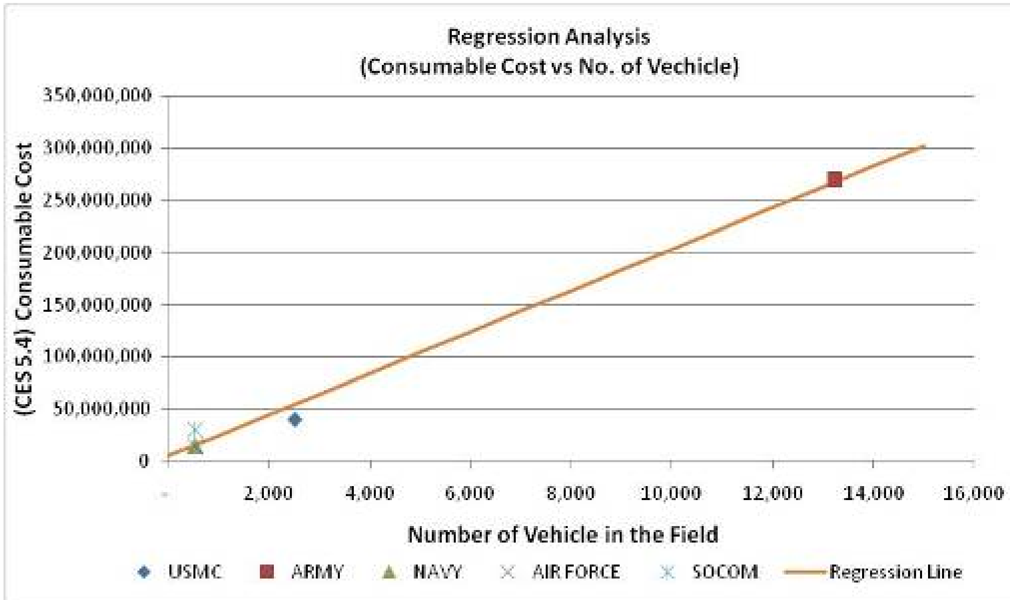

Figure 11. Regression Analysis for CES 5.4 Consumable (FY09)

- CES 5.5 Petroleum, Oil & Lubricant (POL) (as shown in Figure 12)
  - Best fitted relationship – linear
  - p-value of F-test = 3.479E-6
  - p-value of t-test (independent variable) = 3.479E-6
  - p-value of t-test (intercept) = 0.281
  - Coefficient of determination (R^2) = 1.000
  - Adjusted coefficient of determination (adj R^2) = 1.000
  - Function: y = 217443.0 + 2355.0 x

Inference: The relationship between the cost incurred in "Petroleum, Oil & Lubricant (POL)" and the number of operated MRAP vehicles is found to be linear. This is due to the paucity of the underlying data used in the analysis. The p-value of the t-test (intercept) as well as confidence interval (-0.3 to 0.7 million, highlighted in Table 13)

verified that the function is not statistically significant. The number of MRAPs alone is not a good variable for estimating the cost for this element.

Observation: Using this function for the prediction of the cost for SOCOM produces an error of 17%, while it is less than 5% for the Army, Air Force, and Navy.

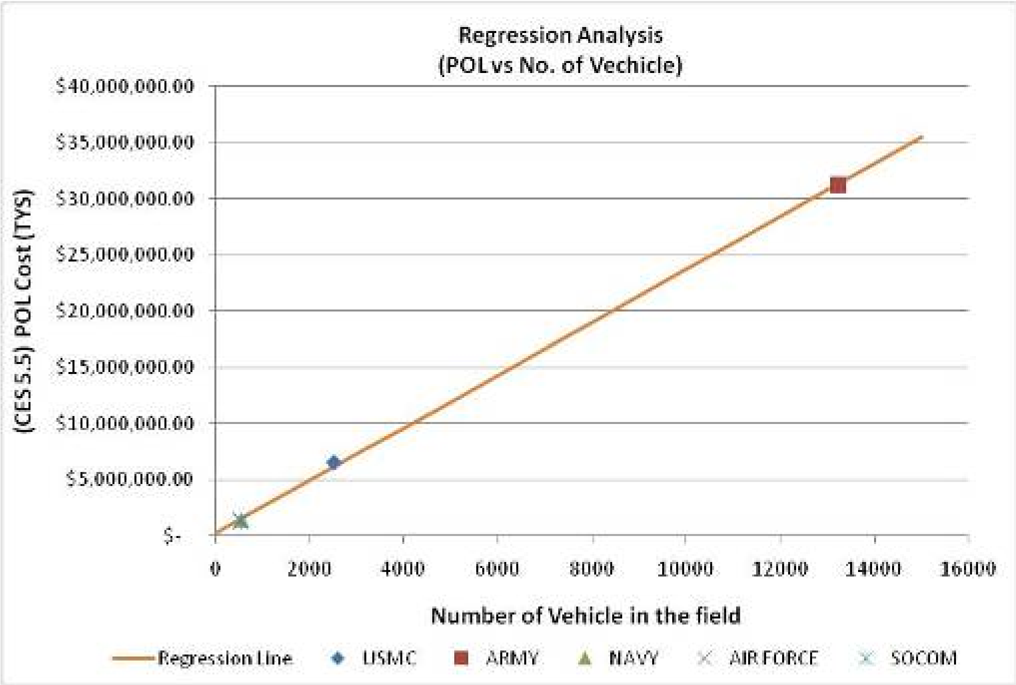

Figure 12. Regression Analysis for CES 5.5 POL (FY09)

- CES 5.6 Sustainment Overhauls (as shown in Figure 13)
  - Best Fitted relationship – linear
  - p-value of F-test = 0.011
  - p-value of t-test (independent variable) = 0.011
  - p-value of t-test (intercept) = 0.114
  - Coefficient of determination (R^2) = 0.912
  - Adjusted coefficient of determination (adj R^2) = 0.883
  - Function: y = 15755830.8 + 6587.2 x

Inference: The identified linear relationship between the cost incurred in "Sustainment Overhauls" and the number of operated MRAP vehicles is not statistically significant due to the paucity of the underlying data used in the analysis. The p-value of the t-test (intercept) and the wide confidence interval (-6.9 to 38.4 million, highlighted in Table 14) confirm that the regression line is not statistically significant.

Observation: The prediction error of this function is acceptable for SOCOM, at less than 5%.

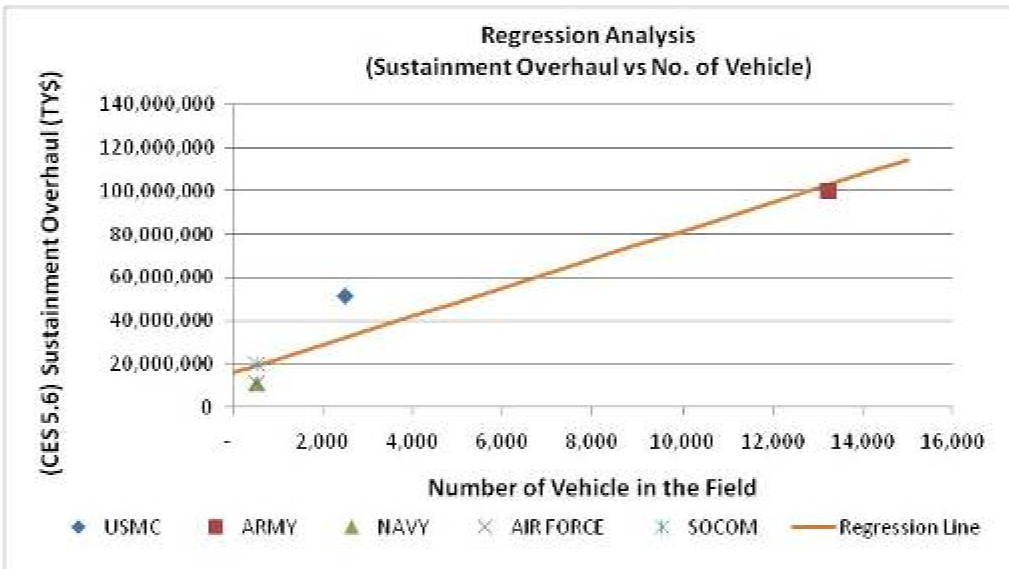

Figure 13. Regression Analysis for CES 5.6 Sustainment Overhaul (FY09)

- CES 5.7.1 Transportation to Theater (as shown in Figure 14)
    - Best fitted relationship – linear
    - p-value of F-test = 2.174E-3
    - p-value of t-test (independent variable) = 2.174E-3
    - p-value of t-test (intercept) = 0.615
    - Coefficient of determination (R^2) = 0.970
    - Adjusted coefficient of determination (adj R^2) = 0.961
    - Function: y = 6125445.0 + 18028.4 x

  Inference: Due to the small sample size used in the analysis, the relationship between the cost incurred in "Transportation to Theater"

and the number of operated MRAP vehicles is shown to be linear. This regression model can be misleading. The high p-value of the intercept and the confidence interval (-28.8 to 41.0 million, highlighted in Table 15) support this finding. The number of MRAPs alone is not a good variable for estimating the cost for this element.

Observation: The prediction error of this function is approximately 50% for SOCOM in FY 2009, while it is acceptable for the Army.

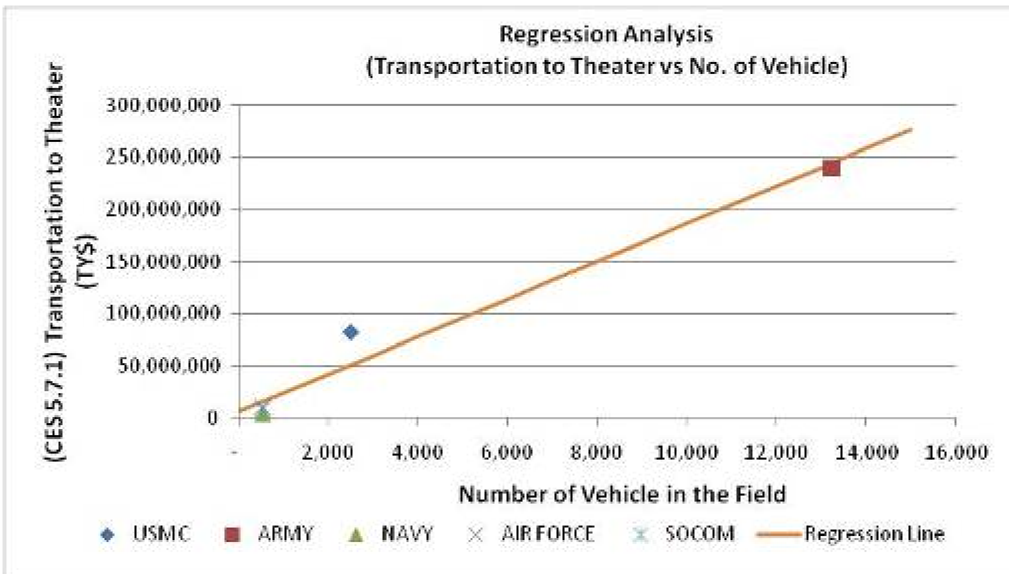

Figure 14. Regression Analysis for CES 5.7.1 Transportation to Theater (FY09)

- CES 5.7.2 Transportation from Theater – no data.
- CES 5.8 Software – no data.
- CES 5.9 System Test & Evaluation – no data.
- CES 5.10.1 Government Program Management (as shown in Figure 15)
    - Best fitted relationship – quadratic
    - p-value of F-test = 1.579E-3
    - p-value of t-test (non-quadratic term) = 9.608E-4
    - p-value of t-test (quadratic term) = 1.096E-3

- p-value of t-test (intercept) = 0.006
- Coefficient of determination (R^2) = 0.998
- Adjusted coefficient of determination (adj R^2) = 0.997

Inference: A quadratic relationship is found to fit all the data points for this cost element. This relationship, however, does not explain why with more vehicles the cost decreases. Further investigation (MRAP JPO, PowerPoint presentation, 2010, slide 14) reveals that this element is funded in accordance to the service staffing in the MRAP JPO, and the high cost in the Marine Corps is due to the fact that the JPO is staffed mainly with personnel from the Marine Corps. As a result, this element cannot be explained with a mathematical function.

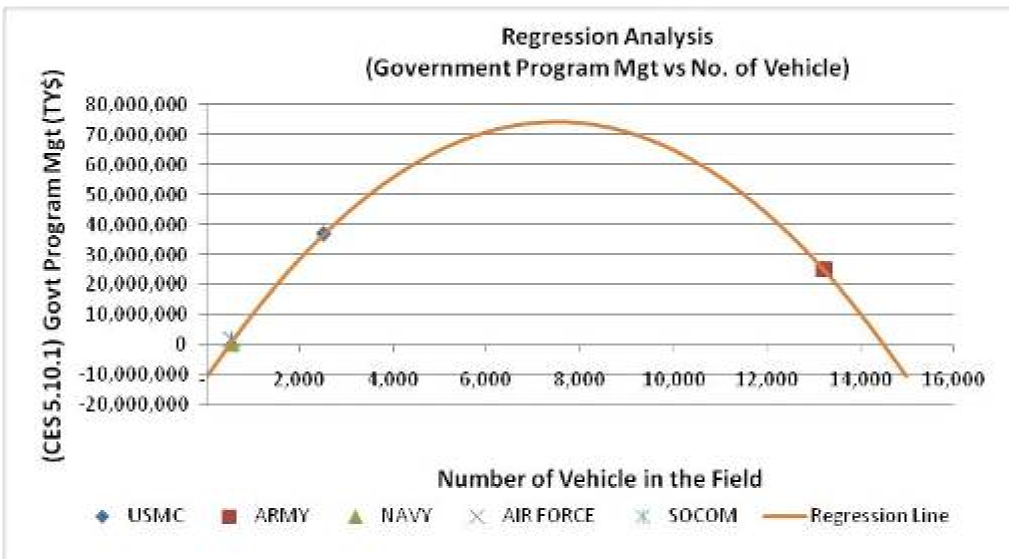

Figure 15. Regression Analysis for CES 5.10.1 Govt Program Mgt (FY09)

- CES 5.10.2 Development Contractor Program Management (as shown in Figure 16)
  - Best fitted relationship – quadratic
  - p-value of F-test = 1.138E-2
  - p-value of t-test (non-quadratic term) = 0.007
  - p-value of t-test (quadratic term) = 0.006

- p-value of t-test (intercept) = 0.353
- Coefficient of determination (R^2) = 0.989
- Adjusted coefficient of determination (adj R^2) = 0.977

- *Inference*: This is the same as CES 5.10.1, in that the element is funded in accordance to the service staffing in the MRAP JPO. Thus, an attempt should not be made to explain this element using a mathematical function.

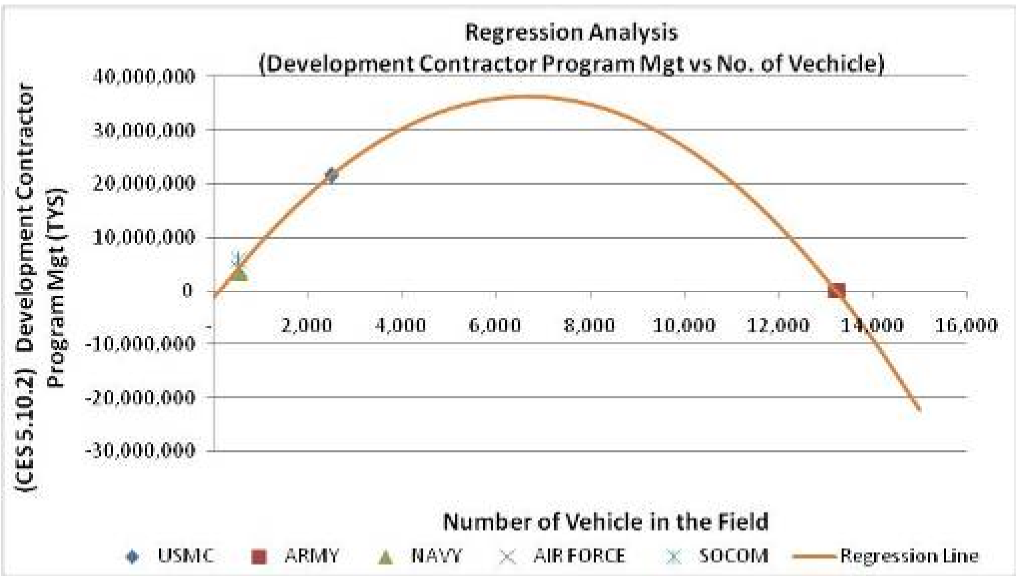

Figure 16. Regression Analysis for CES 5.10.2 Development Contractor Program Mgt (FY09)

- CES 5.11 Training (as shown in Figure 17)
  - Best fitted relationship = linear
  - p-value of F-test = 5.172E-4
  - p-value of t-test (independent variable) = 5.172E-4
  - p-value of t-test (intercept) = 0.165
  - Coefficient of determination (R^2) = 0.989
  - Adjusted coefficient of determination (adj R^2) = 0.985
  - Function: y = 491311.0 + 7194.2 x

  Inference: Due to the paucity of the underlying data used in the analysis, a linear relationship is found to conform to the data points in

"Training." This regression model is, however, unable to explain the high p-value of the intercept as well as a wide confidence interval (-3.7 to 13.5 million, highlighted in Table 18) obtained.

Observation: The prediction error of this function is unacceptable to use for the estimation of this cost element for SOCOM.

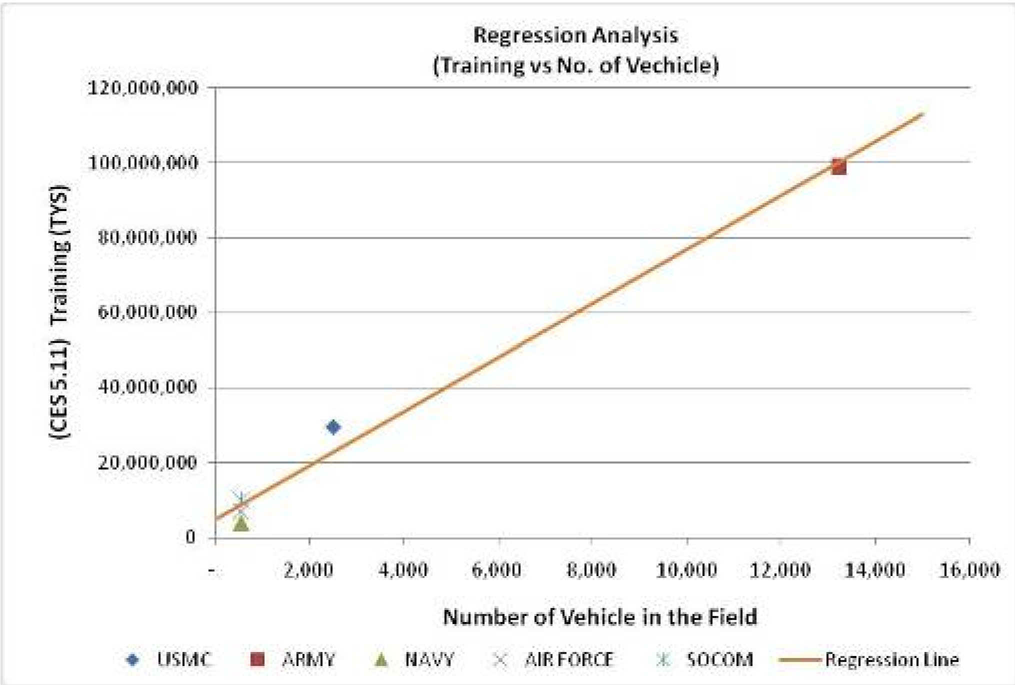

Figure 17. Regression Analysis for CES 5.11 Training (FY09)

- CES 5.12 Contractor Maintenance & Support – SOCOM is the only service funding this element, due to their in-theater contractor logistics support (CLS) agreement.

- CES 5.13 Leased Services & Equipment (as shown in Figure 18)
    - Best fitted relationship = linear
    - p-value of F-test = 1.241E-4
    - p-value of t-test (independent variable) = 1.241E-4
    - p-value of t-test (intercept) = 0.220
    - Coefficient of determination (R^2) = 0.996
    - Adjusted coefficient of determination (adj R^2) = 0.994

- Function: y = 86077.3 + 240.2 x

Inference: There is an apparent linear relationship between the cost incurred in “Leased Services & Equipment” and the number of operated MRAP vehicles. The high p-value of the intercept as well as a wide confidence interval (-0.091 to 0.263 million) (highlighted in Table 19) indicate that the regression line is not statistically significant. The number of MRAPs alone is not a good variable for estimating the cost for this element.

Observation: This function is acceptable for SOCOM, since the prediction error is only about 5%.

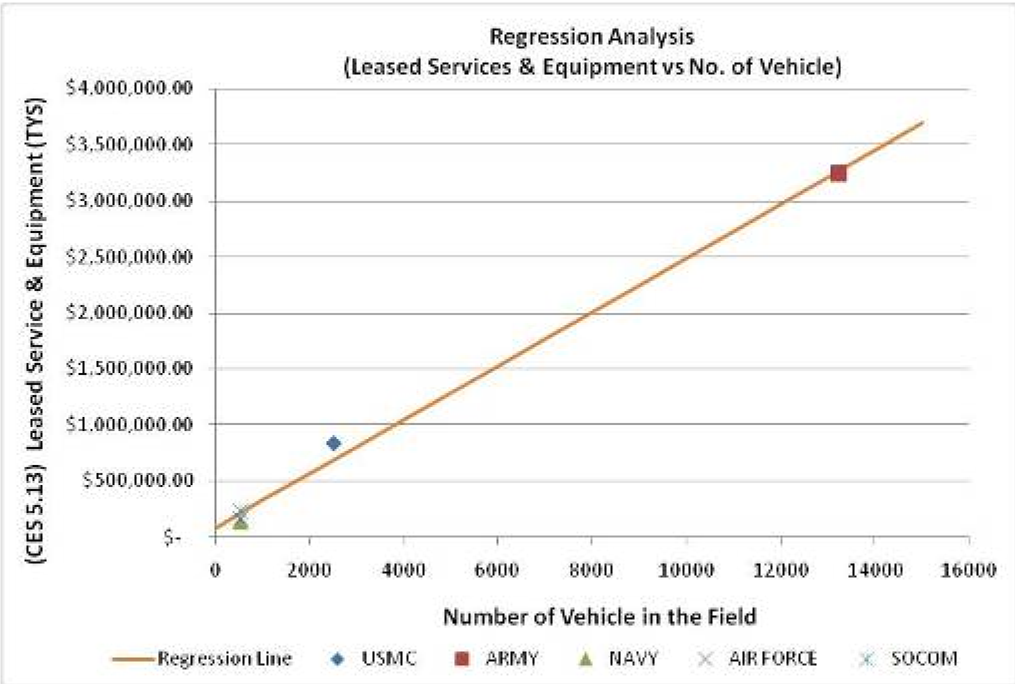

Figure 18. Regression Analysis for CES 5.13 Leased Services & Equipment (FY09)

- CES 5.14 Disposal (as shown in Figure 19)
  - Best fitted relationship – linear
  - p-value of F-test = 4.104E-6
  - p-value of t-test (independent variable) = 4.104E-6

- p-value of t-test (intercept) = 0.303
- Coefficient of determination (R^2) = 1.000
- Adjusted coefficient of determination (adj R^2) = 1.000
- Function: y = 90547.2 + 983.0 x

Inference: The obvious relationship between the cost incurred in "Disposal" and the number of operated MRAP vehicles is linear. This is caused by the shortage of data used in the analysis. The high p-value of the intercept and wide confidence interval (-0.14 to 0.32 million) (highlighted in Table 20) are indicative that the regression line is not statistically significant. The number of MRAPs alone is not a good variable for estimating the cost for this element.

Observation: The prediction error of this function is approximately 17% for SOCOM in FY 2009, while it is acceptable for the Army, Air Force and Navy.

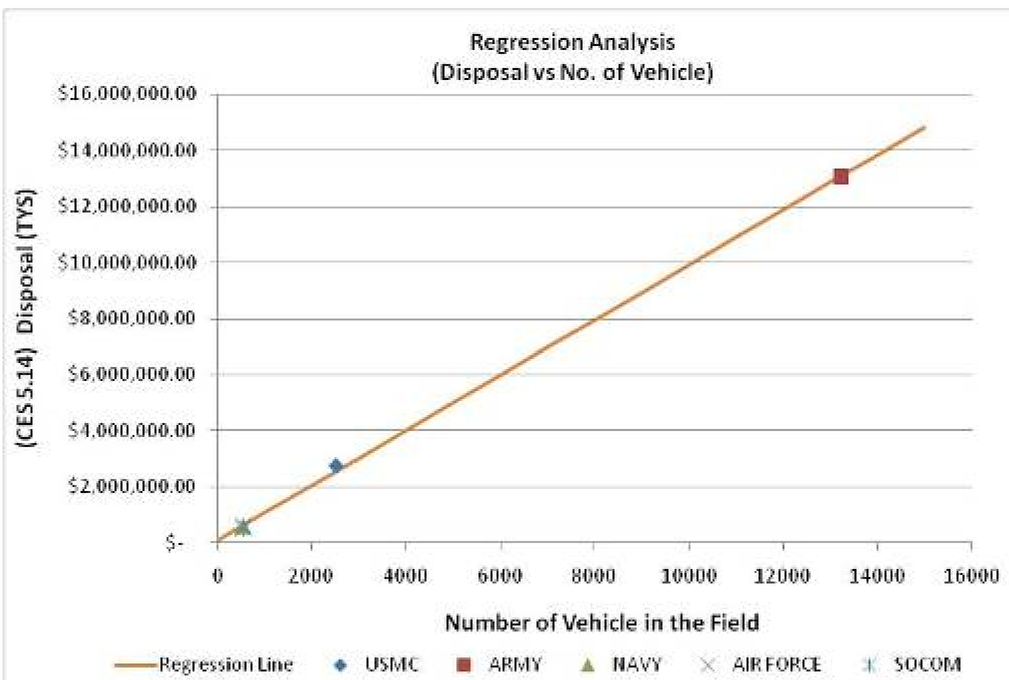

Figure 19. Regression Analysis for CES 5.14 Disposal (FY09)

- CES 5.15.1 Storage – no data.
- CES 5.15.2 Maintenance – no data.
- CES 5.15.3 Transportation to Storage – no data.
- CES 5.15.4 Data Manuals (as shown in Figure 20)
    - Best fitted relationship – linear
    - p-value of F-test = 1.241E-4
    - p-value of t-test (independent variable) = 1.241E-4
    - p-value of t-test (intercept) = 0.220
    - Coefficient of determination (R^2) = 0.996
    - Adjusted coefficient of determination (adj R^2) = 0.994
    - Function: y = 286924.4 + 800.6 x

  Inference: There is an apparent linear relationship between the cost incurred in "Disposal" and the number of operated MRAP vehicles. Due to the paucity of the underlying data used in the analysis, the regression line is not statistically significant. The high p-value of the intercept and the wide confidence interval (-0.30 to 0.88 million, highlighted in Table 21) support the outcome.

  Observation: The prediction error of this function is approximately 5% for SOCOM in FY 2009, implying that it is acceptable for the costing of this element.

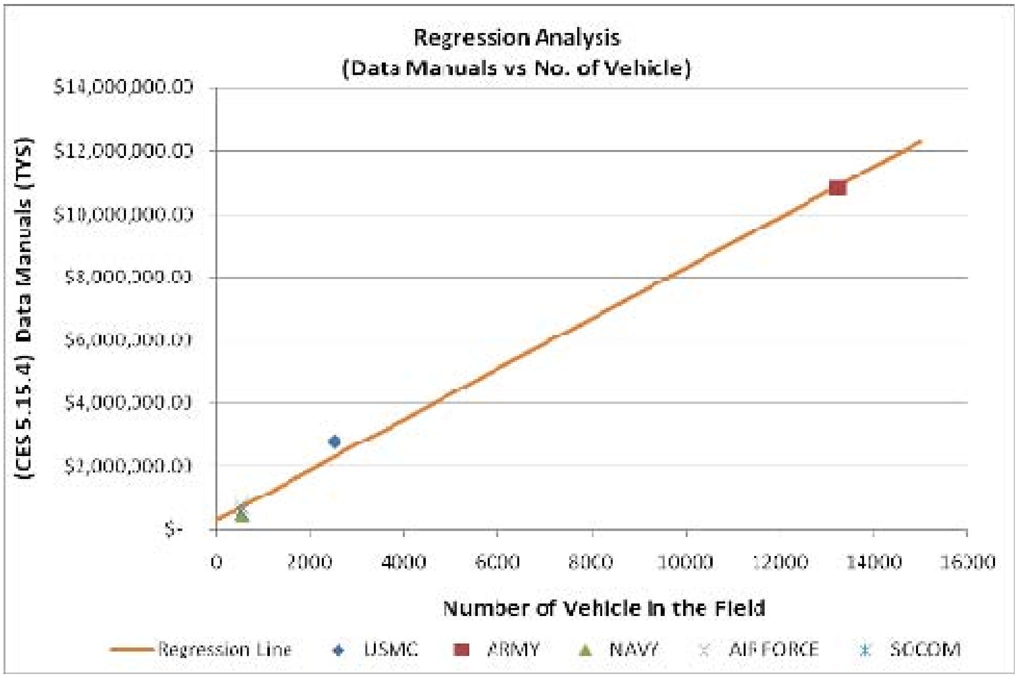

Figure 20. Regression Analysis for CES 5.15.4 Data Manuals (FY09)

C. PROCUREMENT TREND

This section involves the use of learning curve analysis to determine the production trend in the procurement of MRAP vehicles for the period of FY 2007 to 2008. The learning curve analysis is based on the principle that an individual gets better and better when he/she performs the same task over and over again. This phenomenon was first reported by T.P Wright in 1936 (Wright, 1936, pp. 122–128). The slope of the learning curve varies with the task to be performed. The same task in a different industry will yield a different learning curve slope. Table 4 (Heizer & Render, PowerPoint presentation, 2008, slides 7–8) shows some examples of the learning curve slope seen in the different industries. A low percentage value in the slope of the learning curve means that there is significant learning in the process, while a high percentage, on the other hand, denotes slow learning.

Example	Improving Parameters	Cumulative Parameters	Learning Curve Slope (%)
Model-T Ford Production	Price	Units produced	86
Aircraft Assembly	Direct labors-hours per unit	Units produced	80
Equipment Maintenance at GE	Average time to replace a group of parts	Number of replacements	76
Steel Production	Production worker labor-hours per unit produced	Units produced	79
Integrated Circuits	Average price per unit	Units produced	72
Handheld Calculator	Average factory selling price	Units produced	74
Disk Memory Drives	Average price per bit	Number of bits	76
Heart Transplants	1-year death rates	Transplant completed	79

Table 4. Examples of Learning Curve Slopes

The data obtained from the JPO on the LRIP procurement prices for the period of FY 2007 to 2008 on the Category (CAT) I, II, and II MRAP vehicles are shown in Appendix D, sorted by contract date in chronological order. For the CAT I MRAP vehicles, there were five manufacturers contracted during the period of FY 2007 and 2008, namely Armor Holding Aerospace and Defense Group (later acquired by BAE systems); British Aerospace Engineering Systems; General Dynamics Land Systems; Force Protection Industries Inc.; and International Military and Government LLC, with varying orders and quantities. The total number of vehicles ordered was 11,225 amounting to $5,681,158,509, which averages about $506,117 per vehicle.

By applying the learning curve analysis to this data, the curve in Figure 21 is obtained. From computation, the learning curve slope for the CAT I MRAP vehicles for the FY 2007 to FY 2008 is found to be only 99.9%. This rate of learning indicates that the DoD did not use the learning curve analysis in the acquisition of MRAPs, considering that there are nineteen LRIP contracts signed and 11,225 vehicles to be produced, even though there are many variants of the MRAP vehicles.

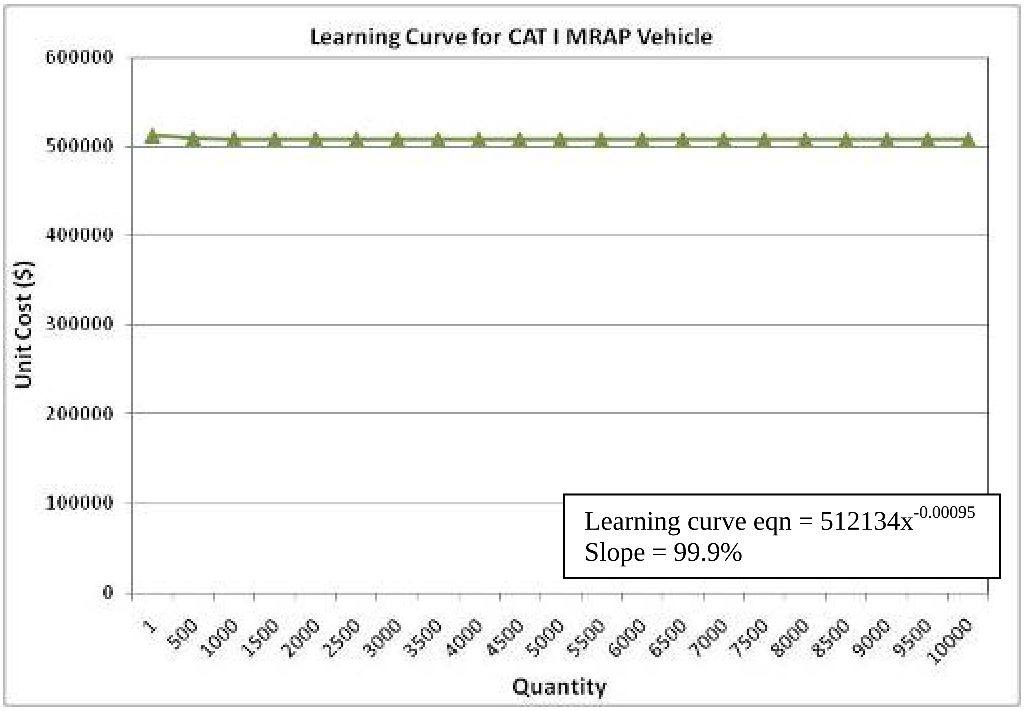

Figure 21. Learning Curve for CAT I MRAP Vehicles

Similarly, the learning curves for CAT II and III MRAP vehicles can be calculated and are shown in Figures 22 and 23. Likewise, the rate of learning is low with the learning curve slopes for the CAT II and III MRAP vehicles for FY 2007 to FY 2008 at 98.3% and 100% respectively. It is noted that there are significantly lesser number of vehicles contracted under CAT II and III. However, this does not explain the fact that there is zero learning (depicted by the horizontal straight line in Figure 23) for the CAT III MRAP vehicles. These learning curve slopes obtained for all the MRAP vehicles from FY 2007 to 2008 are indicative that there is limited to no improvement in the procurement cost.

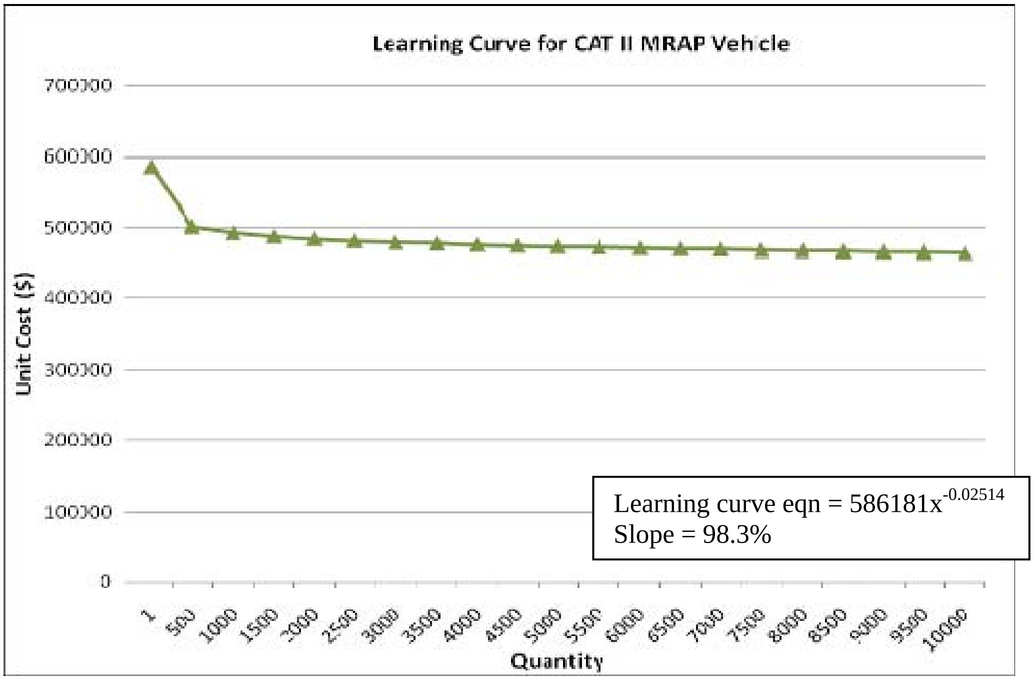

Figure 22. Learning Curve CAT II MRAP Vehicles

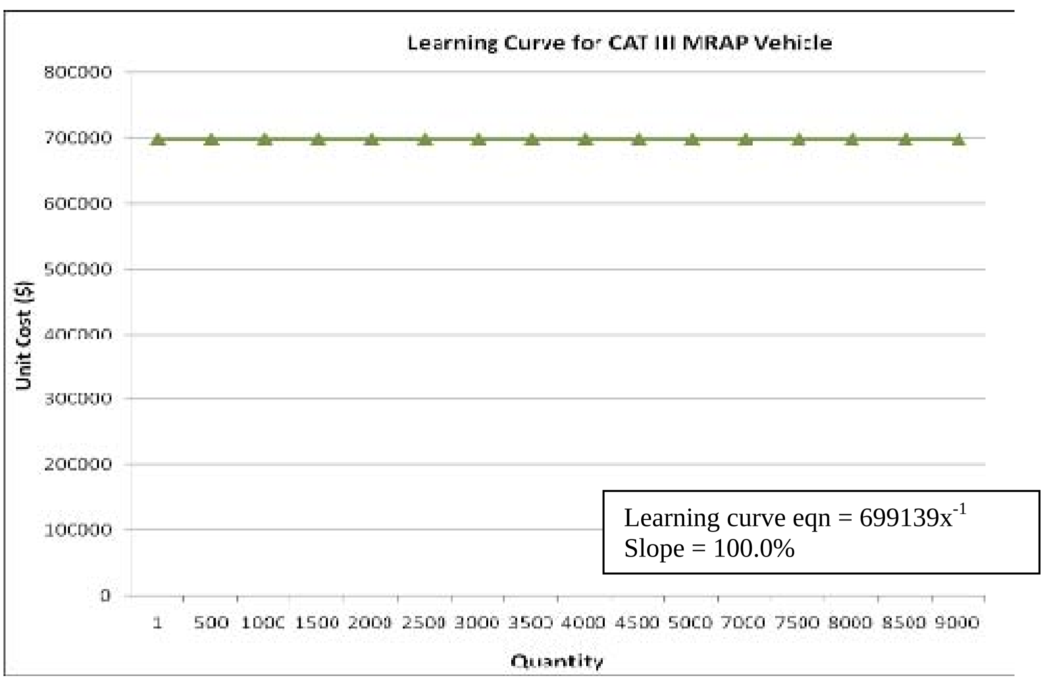

Figure 23. Learning Curve CAT III MRAP Vehicles

D. GOVERNMENT FURNISHED EQUIPMENT

Government furnished equipment (GFE) (U.S. Army Corps of Engineer, 2009, p. 2) refers to equipment in the possession of or acquired directly by the government and subsequently delivered to or made available to the contractor for use or for incorporation into the contractor's work.

Figure 24 shows the cost of the GFE per vehicle incurred by the different services in FY 2008, with the detail on the type of GFEs installed on the vehicles for each service found in Appendix E. The average unit cost of the MRAP vehicle is about $500,000, with different services incurring different costs for their GFE. The ratio of the GFE cost to the acquisition cost is shown above the bar, and it can be seen that the cost of the GFE is in the range of 50% to 60% of the acquisition cost for all the services except SOCOM. In fact, SOCOM appears to spend the same amount on GFE as the basic cost of one single vehicle.

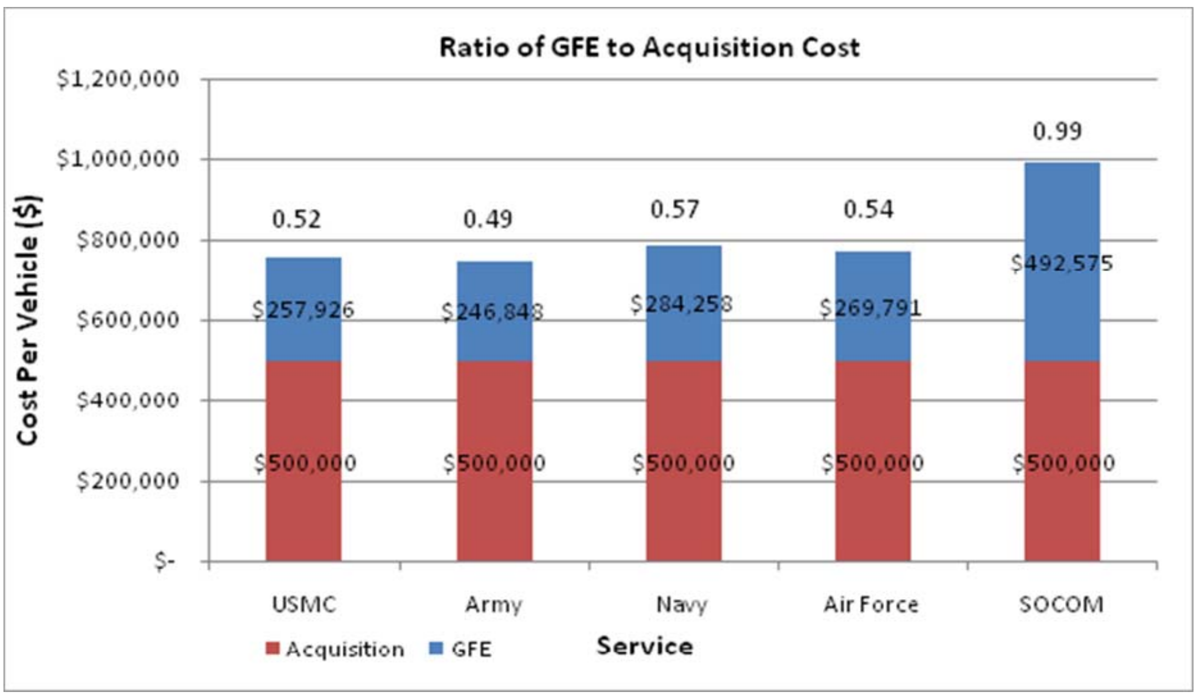

Figure 24. Ratio of GFE to Acquisition Cost for FY 2008

The data in Appendix E also exhibits the following two additional observations:

- Most of the GFE under SOCOM is unique to them and the commonality of this equipment with other services is limited.
- Even though some of the services share similar equipment, the cost incurred is different. A reason for this could be that the order quantity is different.

V. CONCLUSION AND RECOMMENDATION

A. INTRODUCTION

This chapter attempts to answer the questions posted at the start of the thesis, discusses how the results of the analyses will be beneficial to Special Operations Command (SOCOM) for the future Mine Resistant Ambush Protected (MRAP) vehicles sustainment cost estimation, and identifies areas with potential for future research.

B. RESEARCH QUESTIONS ANSWERED

This section uses the finding of the thesis research to answer the questions asked at the beginning of the research.

1. Primary Research Question

- *Question: What parametric/statistical cost-estimating models (e.g., linear or non-linear regression) can explain and be used to predict the future maintenance cost of the MRAP vehicles under the inventory of SOCOM?*

Two known sets of MRAP vehicle data – from the VAMOSC management information system and the MRAP Joint Program Office (JPO) were obtained for use in building a regression model to predict the future maintenance cost of MRAP vehicles under the inventory of SOCOM. From the better data set, which is from the MRAP JPO, the following regression equations (shown in Table 5) were obtained. Due to the paucity of the underlying data, these models turned out to be not statistically significant.

CES	Description	Function
5.1	Field Maintenance	y = 4402965.4 + 14681.1 x
5.2	System Specific Base Ops	y = 823913.5 + 2298.8 x
5.3	Replenishment Spares (Reparables)	y = 4163806.1 + 14723.6 x
5.4	Replenishment Repair Parts (Consumables)	y = 4891670.5 + 19856.1 x
5.5	Petroleum, Oil & Lube (POL)	y = 217443.0 + 2355.0 x
5.6	Sustainment Overhauls	y = 15755830.8 + 6587.2 x
5.7.1	Transportation to Theater	y = 6125445.0 + 18028.4 x
5.7.2	Transportation from Theater	No data
5.8	Software	No data
5.9	System Test & Evaluation	No data
5.10.1	Government Program Management	Based on service staffing.
5.10.2	Development Contractor Program Management	Based on service staffing.
5.11	Training	y = 491311.0 + 7194.2 x
5.12	Contractor Maintenance & Support	Only SOCOM is funding this element.
5.13	Leased Services & Equipment	y = 86077.3 + 240.2 x
5.14	Disposal	y = 90547.2 + 983.0 x
5.15.1	Storage	No data
5.15.2	Maintenance	No data
5.15.3	Transportation to Storage	No data
5.15.4	Data Manuals	y = 286924.4 + 800.6 x

Table 5. Cost Element Relationship (Note: y represents the Cost in $(FY 2009); x represents the Number of Operated MRAP Vehicles)

2. Secondary Research Questions

- *Question One: How much does SOCOM spend annually on running of the MRAP vehicles that are in their inventory?*

The actual data from the MRAP JPO shows that SOCOM incurred a cost of about $150 million in FY 2009 for running 538 MRAP vehicles. Without having more reliable data, estimation can be based on the equations identified in Table 5. However, great care needs to be exercised in the use of the models.

- *Question Two: How does SOCOM's spending compare to that of the other services (i.e. Marine Corps, Army, etc.) or other vehicles (similar function or class) within the service?*

The cost per vehicle for all the cost elements for FY 2009 data is shown in Figure 24 and Table 6. Comparing among the services, SOCOM is observed to have the highest cost per vehicle in the following cost elements (10 out of the total of 14 cost elements that were analyzed):

- Field Maintenance Civilian/Contractor Labor Below Sustainment (CES 5.1) – This element captures the cost of the original equipment manufacturer (OEM) field support representatives (FSRs) who are supporting the maintenance of the vehicles. SOCOM has the highest cost per vehicle in this category because their MRAP vehicles are completely maintained by FSRs while the rest of the services employ a hybrid arrangement of FSRs and organic maintainers;
- System Specific Base Ops (CES 5.2) – This element captures the recurring cost of maintaining the facilities in Iraq, Kuwait and Afghanistan. This cost is proportional to the fleet size operated by the different services;
- Replenishment Spares (Reparable) (CES 5.3) – The parts for SOCOM's vehicles are provided by contractors through the contractor logistics support (CLS) agreement, while the other services obtain their reparable parts through the standard logistics demand and requisition;
- Replenishment Repair Parts (Consumables) (CES 5.4) – The consumables for SOCOM's vehicles are provided by the contractors owing to the contractor logistics support (CLS) agreement;
- Sustainment Overhauls (CES 5.6) – This element deals with the cost of the vehicle overhaul (parts and labor) performed at the MRAP Sustainment Facility (MSF) in Kuwait. The apparent reason for the high cost by SOCOM is due to their unique concept of operation (CONOPS), which translates to having special equipment (See Appendix E) and thus the refurbishment cost is higher;

- Development Contractor Program Management (CES 5.10.2) – The amount that SOCOM incurred in this cost element is directly related to the number of liaison appointments that they have in the MRAP JPO and thus would not be explained with an equation;
- Training (CES 5.11) – This element covers the cost of the new equipment trainers (NET) and the recurring cost (i.e., facilities, supplies, tools, equipment, and contractor personnel) of the MRAP University. It can be deduced that the high cost per vehicle incurred by SOCOM is due to the customized training for their unique CONOPS;
- Contractor Maintenance & Support (CES 5.12) – SOCOM is the only service that is funding this cost element due to their CLS agreement;
- Leased Services & Equipment (CES 5.13) – This element predominately covers the leases of non-tactical vehicles (e.g., SUV) in the theater. These non-tactical vehicles are used mainly by the in-theater civilians, including the FSRs, and the reason why SOCOM is high in this category is because they have more FSRs per vehicle for reason mentioned in CES 5.1 (previous paragraph); and
- Data Manuals (CES 5.15.4) – This element includes the cost of data manual updates driven by the engineering change proposals. SOCOM is the highest because most of their changes are unique while the rest of the services share similar changes and thereby have lower costs.

It can be seen from the above that the reason for the high cost per vehicle spending by SOCOM is probably due to their CLS agreement and their unique CONOPS, which could not be avoided.

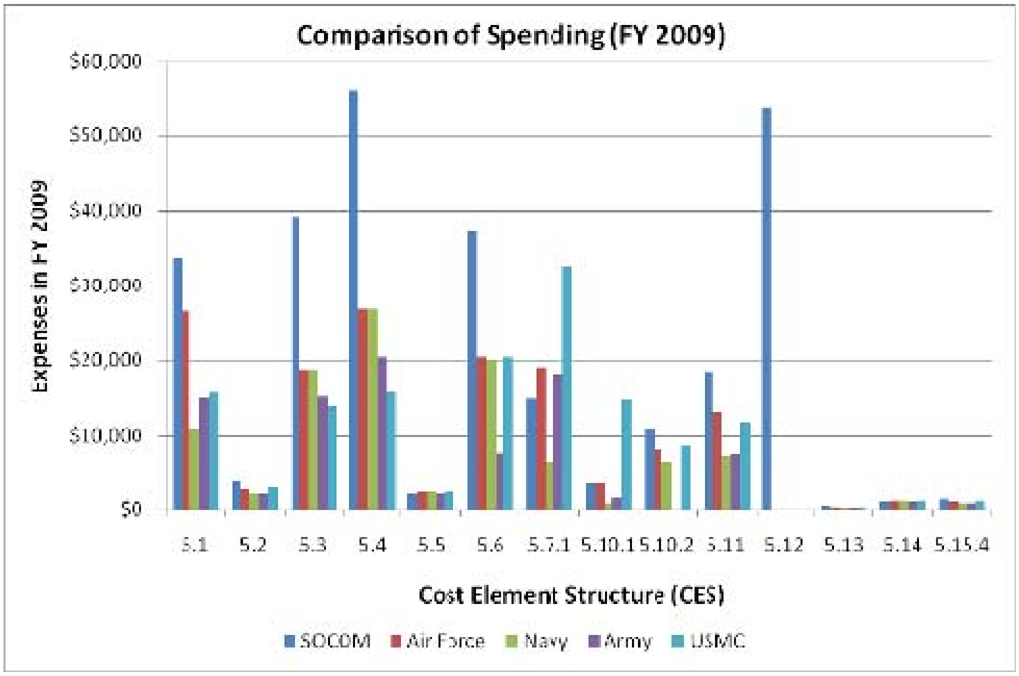

Figure 25. Comparison of Spending (FY2009)

- *Question Three: How does this spending vary with the operational tempo in SOCOM?*

From the "Petroleum, Oil & Lube" (CES 5.5) expenditure of FY 2009 data (Table 6), it can be deduced that the operational tempo is similar for that year. However, this thesis is unable to answer further questions on this issue, due to the lack of historical data on the mileage of the MRAP vehicles.

		USMC	Army	Navy	Air Force	SOCOM	
CES	**Element**	**FY09**	**FY09**	**FY09**	**FY09**	**FY09**	
5.0	**O&M Funded Elements**	**Cost/ Vech**	**Cost/ Vech**	**Cost/ Vech**	**Cost/ Vech**	**Cost/ Vech**	**Highest**
5.1	Field Maintenance Civilian/Contractor Labor Below Sustainment	$15,731	$15,035	$11,029	$26,580	$33,796	SOCOM
5.2	System Specific Base Ops	$3,178	$2,345	$2,342	$2,929	$4,045	SOCOM
5.3	Replenishment Spares (Reparables)	$13,939	$15,110	$18,826	$18,872	$39,275	SOCOM
5.4	Replenishment Repair Parts (Consumables)	$15,930	$20,399	$26,885	$26,950	$56,088	SOCOM
5.5	Petroleum, Oil & Lube (POL)	$2,711	$2,405	$2,677	$2,640	$2,315	USMC
5.6	Sustainment Overhauls	$20,418	$7,555	$20,034	$20,508	$37,134	SOCOM
5.7.1	Transportation to Theater	$32,656	$18,132	$6,297	$19,147	$14,870	USMC
5.10.1	Government Program Management	$14,735	$1,889	$903	$3,690	$3,717	USMC
5.10.2	Development Contractor Program Management	$8,665	$0	$6,385	$7,984	$11,028	SOCOM
5.11	Training	$11,750	$7,489	$7,133	$13,011	$18,587	SOCOM
5.12	Contractor Maintenance & Support	$0	$0	$0	$0	$53,903	SOCOM
5.13	Leased Services & Equipment	$332	$245	$245	$306	$423	SOCOM
5.14	Disposal/ Demilitarization	$1,098	$988	$1,092	$1,089	$959	USMC
5.15.4	Data Manuals	$1,107	$817	$816	$1,020	$1,409	SOCOM

Table 6. Cost per Vehicle of the Various Cost Element O&M Funded Elements for All the Services

C. OTHER ISSUES

Aside from the regression analysis performed in Chapter IV, the learning curve analysis also concluded that the learning in the vehicles procurement for the MRAP program was poor. As it is not an objective of this thesis, the cause for the “flat” curves for the Category (CAT) I, II and III MRAP vehicles was not investigated. This is definitely an area for further research.

In addition, the cost per vehicle of the government furnished equipment (GFE) for SOCOM was noticed to be significantly higher than the rest of the services. The apparent cause is that SOCOM has uncommon CONOPS requiring special or expensive equipment. This is another area for further research.

D. BENEFIT AND RECOMMENDATION TO SOCOM

In a nutshell, this study attempts to provide a statistically-supported method, using parametric technique of regression analysis on historical data, for SOCOM to estimate the cost of running their MRAP vehicles. As is often the case in cost estimating, the shortage of data was a problem, so one should exercise great care in using these models.

As SOCOM is a unique service of the U.S. military, their CONOPS involving the MRAP vehicles is not the same as the rest of the services of the U.S. military. This means that the O&M cost of running these vehicles cannot be adequately answered by the historical data from the other services. Therefore, it is recommended that SOCOM embark on a program similar to the Visibility & Management of Operation & Support Cost (VAMOSC) management information system established by the Department Of Defense (DoD) so that there will be historical data available for future sustainment budgetary estimation of their weapon systems.

In addition, the examination of historical data using the VAMOSC management information system for the Army and Marine Corps has led to the exposure of areas of discrepancy. It is important that corrective actions be taken to correct the errors made so that it does not become a major problem downstream.

E. PROSPECT OF FUTURE RESEARCH

It is surmised by the author that the work done in this thesis revealed problems with the current data and as a result, produced a weak approach for the estimation of the O&M cost of running SOCOM MRAP vehicles for the purpose of budgetary sustainment. There are a few factors that implied there is a need for re-evaluation of the cost-estimating relationship within the next five years. Firstly, the running of the MRAP vehicles in the U.S. military is going to be for at least another twenty years, if not more. Therefore, periodic examination of the cost-estimating relationship helps to maintain the precision of this relationship. Secondly, the fact that O&M data from the VAMOSC management information system on the MRAP vehicles was not used in the analysis implies that re-evaluation should be carried out when the data becomes more mature. Thirdly, the unanswered secondary research question of how the O&M cost of the MRAP vehicles responds to a change in the operational tempo is another area to be looked into.

APPENDIX A. COMPLETE DATA FROM VAMOSC AND OSMIS

Fiscal Year	TAMCN	TAMCN Description	Org Consumable Parts Cost	Org Reparable Parts Cost	Int Consumable Parts Cost	Int Reparable Parts Cost	Int Labor Cost	Org Labor Cost	Int Labor Hours	Org Labor Hours	Inventory
2007	D0023	MRAP Cougar, 6X6									14
2007	D0024	MRAP Cougar, 4X4									16
2007	D0025	MRAP JERRV, 4X4									125
2007	D0026	MRAP Buffalo									23
2007	D0027	MRAP JERRV, 6X6									181
2008	D0023	MRAP Cougar, 6X6					$70.57	$0.00	$2.61	$0.00	8
2008	D0025	MRAP JERRV, 4X4	$1,036.82	$0.00	$0.00	$0.00	$117.62	$96,863.48	$4.35	$3,582.66	1157
2008	D0026	MRAP Buffalo	$0.00	$0.00	$0.00	$0.00	$0.00	$141.14	$0.00	$5.22	16
2008	D0027	MRAP JERRV, 6X6	$1,987.86	$23,285.29	$0.00	$0.00	$47.05	$6,327.41	$1.74	$234.03	461
2009	D0024	MRAP Cougar, 4X4	$0.00	$0.00	$0.00	$0.00	$0.00	$24.59	$0.00	$0.87	
2009	D0025	MRAP JERRV, 4X4	$310,164.70	$303,985.21	$15,005.92	$23,285.29	$1,130.97	$150,713.41	$40.02	$5,333.10	
2009	D0027	MRAP JERRV, 6X6	$93,131.42	$0.00	$783.89	$0.00	$196.69	$18,931.37	$6.96	$669.90	

Table 7. Consumable and Reparable Data from Marine Corps' VAMOSC Management Information System

MDS	MDSNAME	FY	QTR	CONS SSF WHOLESALE EXTCOST($)	REPS SSF WHOLESALE EXTCOST($)	TOTAL SSF EXTCOST($)	DENSITY
RG-31 CHARGER	MRAP	2007	1	1,291.13	0.00	1,291.13	145
RG-31 CHARGER	MRAP	2007	2	1,323.97	0.00	1,323.97	124
RG-31 CHARGER	MRAP	2007	3	933.16	0.00	933.16	89
RG-31 CHARGER	MRAP	2007	4	1,186.26	0.00	1,186.26	81
HAGA -1053	MRAP AMBULANCE	2008	4	1,424,442.45	110,064.32	1,534,506.77	121
MK1-2251	MRAP BUFFALO	2008	1	19,168.19	600.06	19,768.25	9
MK1-2251	MRAP BUFFALO	2008	2	13,592.55	276.04	13,868.59	13
MK1-2251	MRAP BUFFALO	2008	3	10,747.84	515.76	11,263.60	12
MK1-2251	MRAP BUFFALO	2008	4	189,712.43	14,845.21	204,557.64	12
MRAP-2717	MRAP CAIMAN	2008	4	1,018,643.43	113,276.89	1,131,920.32	298
XM1220-0908	MRAP CAIMAN	2008	3	15,945.80	34,243.39	50,189.19	305
XM1220-0908	MRAP CAIMAN	2008	4	1,106,509.45	109,018.69	1,215,528.13	836
RG-31	MRAP CHARGER	2008	1	1,099.14	360.02	1,459.16	65
RG-31	MRAP CHARGER	2008	2	1,319.05	472.18	1,791.23	23
RG-31	MRAP CHARGER	2008	3	3,042.59	493.73	3,536.32	27
RG-31	MRAP CHARGER	2008	4	398,504.21	220.55	398,724.76	34
RG-31-9926	MRAP CHARGER	2008	2	3.78	1,497.79	1,501.57	12
RG-31-9926	MRAP CHARGER	2008	3	205.19	72.93	278.12	8
RG-31-9926	MRAP CHARGER	2008	4	12,312.22	266.16	12,578.38	20
RG-31-9932	MRAP CHARGER	2008	1	2,966.66	1,082.73	4,049.38	17
RG-31-9932	MRAP CHARGER	2008	2	3,253.64	671.53	3,925.16	23
RG-31-9932	MRAP CHARGER	2008	3	8,871.95	441.63	9,313.58	24
RG-31-9932	MRAP CHARGER	2008	4	785,184.59	8,857.43	794,042.03	40
JERRV	MRAP COUGAR	2008	2	132,390.41	581.51	132,971.91	4
JERRV	MRAP COUGAR	2008	3	3,052,742.69	38,149.07	3,090,891.76	9
JERRV	MRAP COUGAR	2008	4	2,757,795.21	99,401.77	2,857,196.97	16
JERRV-2246	MRAP COUGAR	2008	1	1,009.49	360.02	1,369.51	33
JERRV-2246	MRAP COUGAR	2008	2	82,582.77	305.97	82,888.74	66
JERRV-2246	MRAP COUGAR	2008	3	2,527,182.55	32,160.97	2,559,343.52	76
JERRV-2246	MRAP COUGAR	2008	4	2,419,456.02	90,849.57	2,510,305.59	68
JERRV-5199	MRAP COUGAR	2008	3	5,240.45	67.60	5,308.05	2
JERRV-5199	MRAP COUGAR	2008	4	481,775.88	13,800.33	495,576.21	201
MRAP-0281	MRAP MAXXPRO	2008	3	12,958.19	675.96	13,634.15	11
MRAP-0281	MRAP MAXXPRO	2008	4	8,810.15	3,214.29	12,024.44	282
XM1224-4634	MRAP MAXXPRO	2008	3	201,856.41	14,314.67	216,171.08	696
XM1224-4634	MRAP MAXXPRO	2008	4	1,582,824.78	17,983.33	1,600,808.11	1,840
JERRV-5169	MRAP RG-31	2008	4	4,941.88	137.76	5,079.64	577
XM1221-5581	MRAP RG-31	2008	2	58.90	0.00	58.90	53
XM1221-5581	MRAP RG-31	2008	3	28,490.93	0.00	28,490.93	398
XM1221-5581	MRAP RG-31	2008	4	88,555.44	153.97	88,709.41	427
RG-33L-4677	MRAP RG-33L	2008	3	84,747.26	1,383.92	86,131.18	72
RG-33L-4677	MRAP RG-33L	2008	4	1,933,645.98	25,949.05	1,959,595.04	566

Table 8. Consumable and Reparable Data from OSMIS

APPENDIX B. SCATTER PLOTS OF THE VAMSOC AND OSMIS DATA

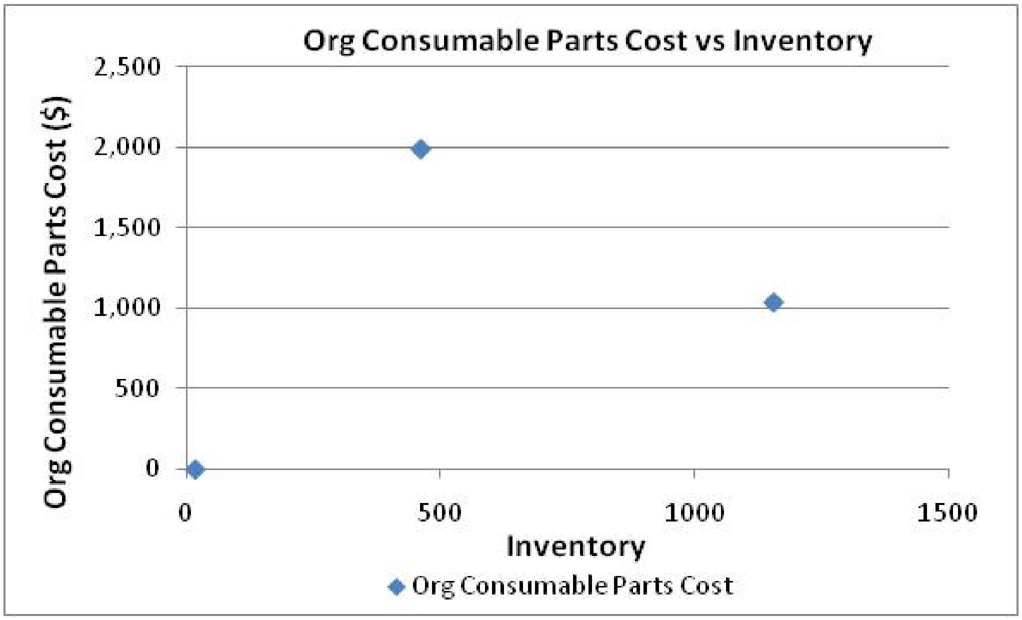

Figure 26. Scatter Plot of the Org Consumable Cost versus Inventory (VAMOSC)

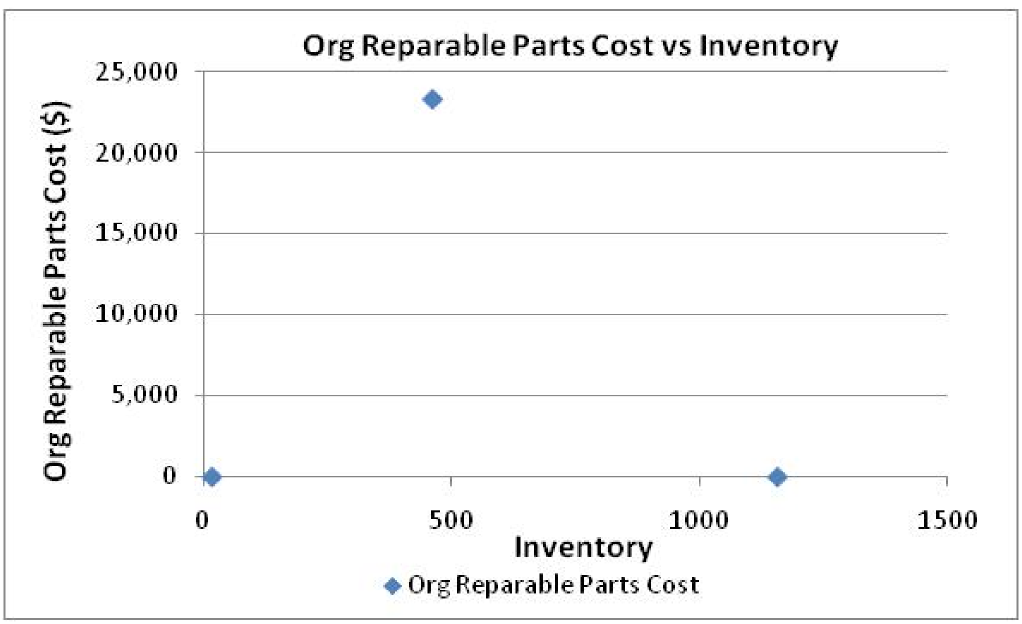

Figure 27. Scatter Plot of the Org Reparable Cost versus Inventory (VAMOSC)

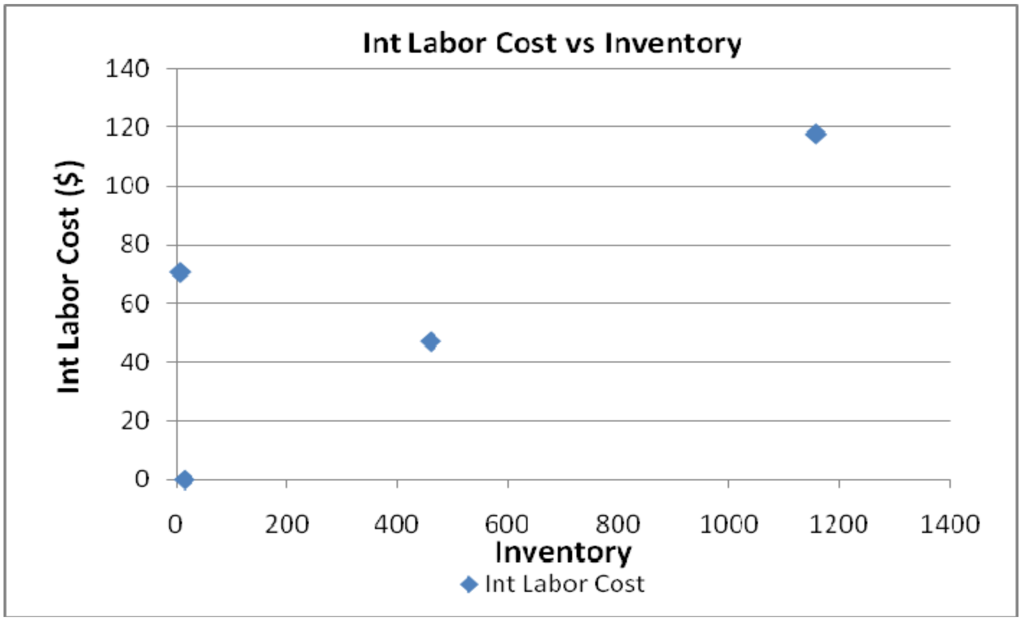

Figure 28. Scatter Plot of the Int Labor Cost versus Inventory (VAMOSC)

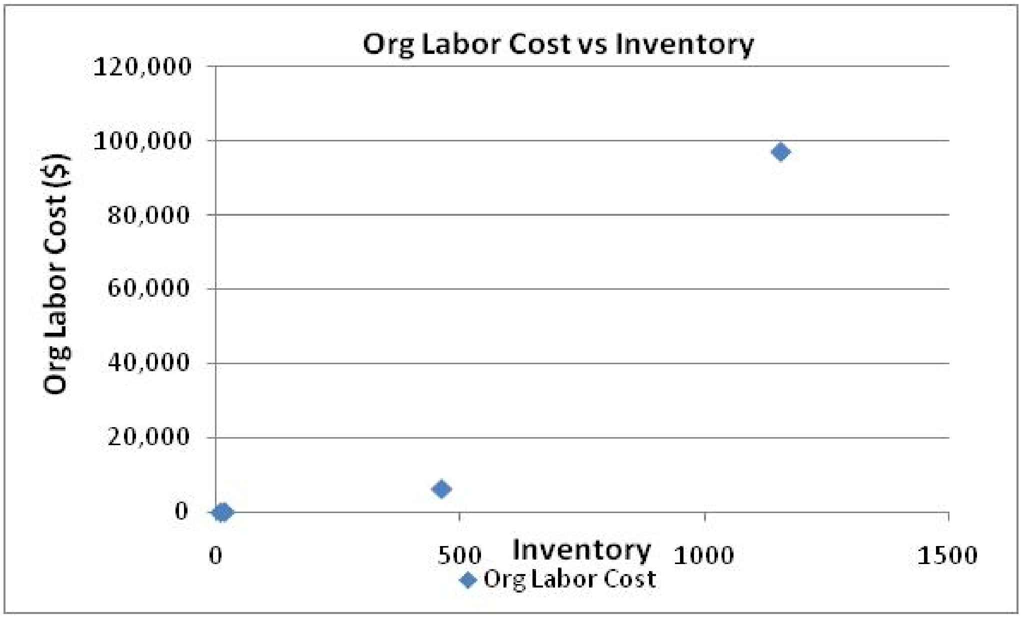

Figure 29. Scatter Plot of the Org Labor Cost versus Inventory (VAMOSC)

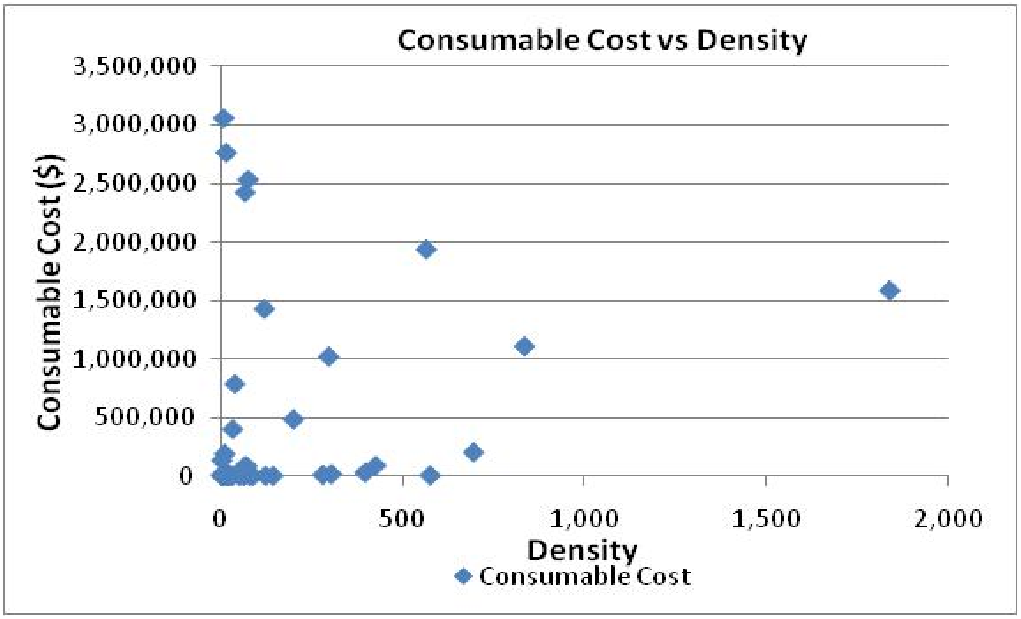

Figure 30. Scatter Plot of the Consumable Cost versus Density (OSMIS)

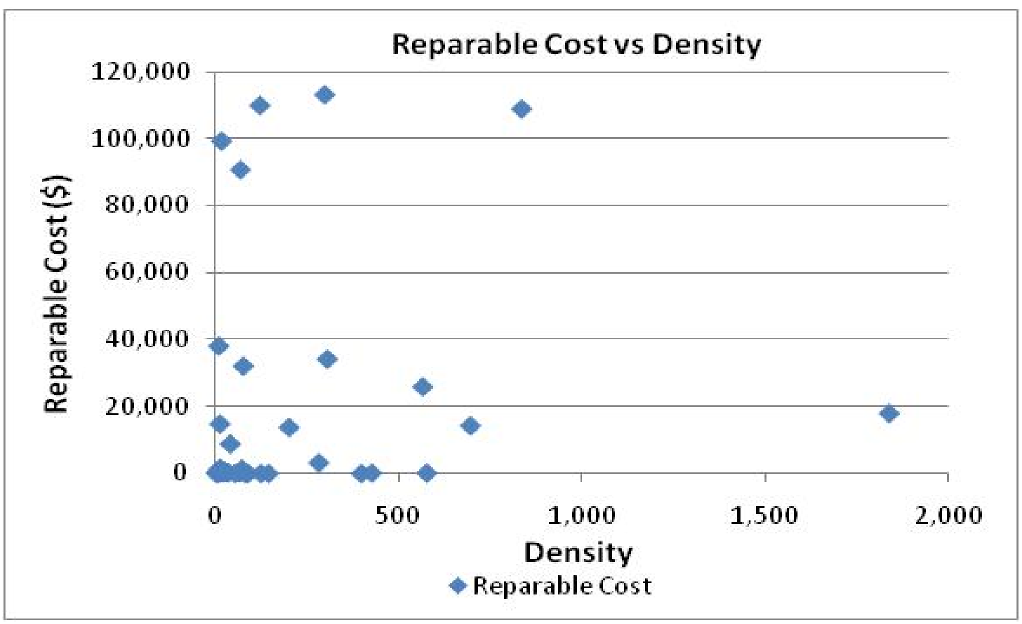

Figure 31. Scatter Plot of the Reparable Cost versus Density (OSMIS)

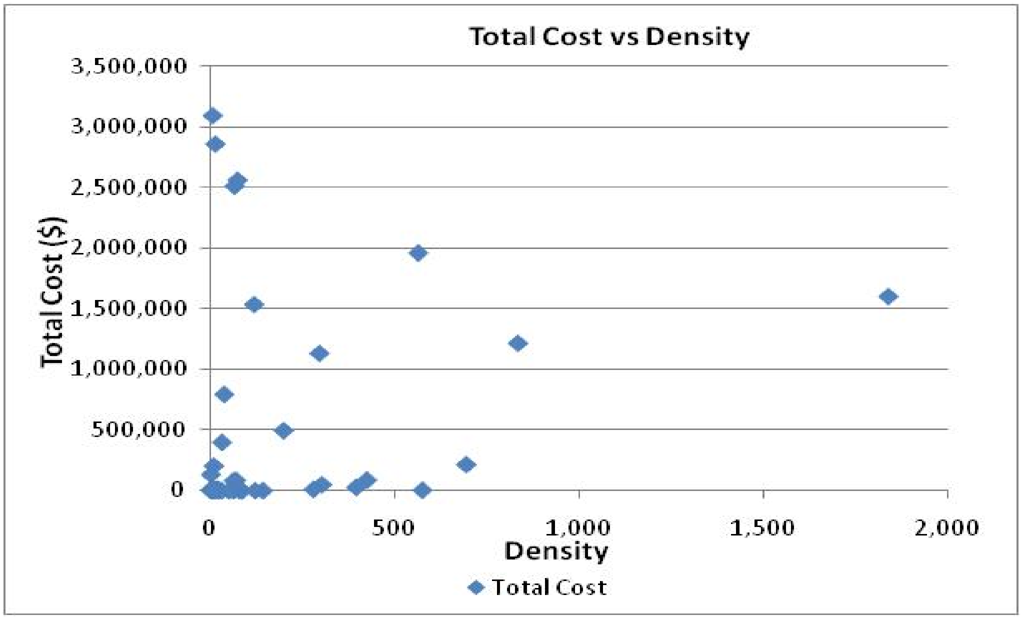

Figure 32. Scatter Plot of the Total Cost versus Density (OSMIS)

APPENDIX C. ANALYSIS ON MRAP JPO DATA

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.998433669
R Square	0.996869792
Adjusted R Square	0.995826389
Standard Error	5247270.881
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2.63059E+16	2.63059E+16	955.4027953	7.43973E-05
Residual	3	8.26016E+13	2.75339E+13		
Total	4	2.63885E+16			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	4402965.415	2868532.924	1.534918905	0.222367343	-4725986.59	13531917.42	-4725986.59	13531917.42
X Variable 1	14681.12857	474.9700093	30.90959067	7.43973E-05	13169.56202	16192.69512	13169.56202	16192.69512

Table 9. Excel Data Analysis Output for CES 5.1 Field Maintenance

SUMMARY
OUTPUT

Regression Statistics	
Multiple R	0.997796616
R Square	0.995598087
Adjusted R Square	0.994130783
Standard Error	974968.3331
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	6.44978E+14	6.44978E+14	678.5218956	0.000124115
Residual	3	2.85169E+12	9.50563E+11		
Total	4	6.4783E+14			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	823913.4604	532987.3046	1.545840686	0.219864166	-872290.0178	2520116.939	-872290.0178	2520116.939
Number of Vehicle	2298.820954	88.25172718	26.04845285	0.000124115	2017.964571	2579.677337	2017.964571	2579.677337

Table 10. Excel Data Analysis Output for CES 5.2 System Specific Base Ops

SUMMARY
OUTPUT

Regression Statistics	
Multiple R	0.998433669
R Square	0.996869792
Adjusted R Square	0.995826389
Standard Error	5247270.881
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2.63059E+16	2.63059E+16	955.4027953	7.43973E-05
Residual	3	8.26016E+13	2.75339E+13		
Total	4	2.63885E+16			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	4402965.415	2868532.924	1.534918905	0.222367343	-4725986.59	13531917.42	-4725986.59	13531917.42
X Variable 1	14681.12857	474.9700093	30.90959067	7.43973E-05	13169.56202	16192.69512	13169.56202	16192.69512

Table 11. Excel Data Analysis Output for CES 5.3 Replenishment Spares (Repairables)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.995476396
R Square	0.990973254
Adjusted R Square	0.987964339
Standard Error	12087492.43
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	4.81199E+16	4.81199E+16	329.3456845	0.000364977
Residual	3	4.38322E+14	1.46107E+14		
Total	4	4.85582E+16			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	4891670.45	6607886.423	0.740277622	0.512803533	-16137573.28	25920914.18	-16137573.28	25920914.18
Number of Vehicle	19856.14371	1094.129982	18.14788375	0.000364977	16374.13379	23338.15363	16374.13379	23338.15363

Table 12. Excel Data Analysis Output for CES 5.4 Replenishment Repair Parts (Consumables)

SUMMARY
OUTPUT

Regression Statistics	
Multiple R	0.999796733
R Square	0.999593507
Adjusted R Square	0.999458009
Standard Error	302909.0681
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	6.76886E+14	6.76886E+14	7377.192582	3.47874E-06
Residual	3	2.75262E+11	91753903529		
Total	4	6.77161E+14			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	217442.9839	165591.7246	1.313127117	0.280547779	-309543.7883	744429.7561	-309543.7883	744429.7561
Number of Vehicle	2354.99798	27.41858123	85.89058494	3.47874E-06	2267.739818	2442.256143	2267.739818	2442.256143

Table 13. Excel Data Analysis Output for CES 5.5 Petroleum, Oil & Lube (POL)

SUMMARY
OUTPUT

Regression Statistics	
Multiple R	0.955177732
R Square	0.912364501
Adjusted R Square	0.883152667
Standard Error	13021572.11
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	5.29586E+15	5.29586E+15	31.2327027	0.011314437
Residual	3	5.08684E+14	1.69561E+14		
Total	4	5.80454E+15			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	15755830.79	7118521.071	2.21335733	0.113744934	-6898480.285	38410141.87	-6898480.285	38410141.87
X Variable 1	6587.200881	1178.680569	5.588622612	0.011314437	2836.113259	10338.2885	2836.113259	10338.2885

Table 14. Excel Data Analysis Output for CES 5.6 Sustainment Overhauls

SUMMARY
OUTPUT

Regression Statistics	
Multiple R	0.985120277
R Square	0.97046196
Adjusted R Square	0.960615946
Standard Error	20061606.05
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3.96688E+16	3.96688E+16	98.56394848	0.002173974
Residual	3	1.2074E+15	4.02468E+14		
Total	4	4.08762E+16			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	6125444.964	10967106.29	0.558528823	0.615460998	-28776781.92	41027671.85	-28776781.92	41027671.85
X Variable 1	18028.41091	1815.927066	9.927937776	0.002173974	12249.32053	23807.50129	12249.32053	23807.50129

Table 15. Excel Data Analysis Output for CES 5.7.1 Transportation to Theater

SUMMARY
OUTPUT

Regression Statistics	
Multiple R	0.999210359
R Square	0.998421341
Adjusted R Square	0.996842683
Standard Error	939549.7192
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.11659E+15	5.58297E+14	632.4491878	0.001578659
Residual	2	1.76551E+12	8.82754E+11		
Total	4	1.11836E+15			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-10276533.19	787440.1666	-13.05055752	0.005820194	-13664614.77	-6888451.607	-13664614.77	-6888451.607
x	22609.92535	701.3281088	32.23872687	0.000960767	19592.35405	25627.49665	19592.35405	25627.49665
x^2	-1.50685421	0.049929588	-30.17958422	0.001096122	-1.721683888	-1.292024531	-1.721683888	-1.292024531

Table 16. Excel Data Analysis Output for CES 5.10.1 Government Program Management

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.994291743
R Square	0.988616071
Adjusted R Square	0.977232142
Standard Error	1279466.668
Observations	5

ANOVA

	df	SS	MS	F	Significance F
Regression	2	2.8433E+14	1.42165E+14	86.84313311	0.011383929
Residual	2	3.27407E+12	1.63703E+12		
Total	4	2.87605E+14			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-1286871.058	1072325.845	-1.200074645	0.352979963	-5900716.781	3326974.665	-5900716.781	3326974.665
x	11300.84277	955.0595571	11.83260529	0.0070667	7191.553157	15410.13238	7191.553157	15410.13238
x^2	-0.846449853	0.067993468	-12.44898779	0.006390769	-1.139002134	-0.553897572	-1.139002134	-0.553897572

Table 17. Excel Data Analysis Output for CES 5.10.2 Development Contractor Program Management

SUMMARY
OUTPUT

Regression Statistics	
Multiple R	0.994292221
R Square	0.988617021
Adjusted R Square	0.984822695
Standard Error	4923841.653
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	6.31686E+15	6.31686E+15	260.5513978	0.000517205
Residual	3	7.27326E+13	2.42442E+13		
Total	4	6.3896E+15			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	4913111.037	2691723.415	1.825265928	0.165448917	-3653154.199	13479376.27	-3653154.199	13479376.27
Number of Vehicle	7194.216204	445.6939939	16.14160456	0.000517205	5775.819	8612.613407	5775.819	8612.613407

Table 18. Excel Data Analysis Output for CES 5.11 Training

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.997796616
R Square	0.995598087
Adjusted R Square	0.994130783
Standard Error	101858.5703
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	7.03978E+12	7.03978E+12	678.5218956	0.000124115
Residual	3	31125505011	10375168337		
Total	4	7.0709E+12			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	86077.30554	55683.16732	1.545840686	0.219864166	-91131.38453	263285.9956	-91131.38453	263285.9956
Number of Vehicle	240.1663805	9.219986382	26.04845285	0.000124115	210.8242689	269.5084921	210.8242689	269.5084921

Table 19. Excel Data Analysis Output for CES 5.13 Leased Services & Equipment

SUMMARY
OUTPUT

Regression Statistics	
Multiple R	0.99977305
R Square	0.999546152
Adjusted R Square	0.99939487
Standard Error	133603.5931
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.17937E+14	1.17937E+14	6607.148571	4.10405E-06
Residual	3	53549760230	17849920077		
Total	4	1.17991E+14			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	90547.18615	73037.2634	1.239739579	0.303208859	-141889.9829	322984.3552	-141889.9829	322984.3552
Number of Vehicle	983.0098689	12.09346749	81.28436855	4.10405E-06	944.523058	1021.49668	944.523058	1021.49668

Table 20. Excel Data Analysis Output for CES 5.14 Disposal

SUMMARY
OUTPUT

Regression Statistics	
Multiple R	0.997796616
R Square	0.995598087
Adjusted R Square	0.994130783
Standard Error	339528.5676
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	7.82198E+13	7.82198E+13	678.5218956	0.000124115
Residual	3	3.45839E+11	1.1528E+11		
Total	4	7.85656E+13			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	286924.3518	185610.5577	1.545840686	0.219864166	-303771.2818	877619.9854	-303771.2818	877619.9854
Number of Vehicle	800.5546017	30.73328794	26.04845285	0.000124115	702.7475631	898.3616404	702.7475631	898.3616404

Table 21. Excel Data Analysis Output for CES 5.15.4 Data Manuals

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APPENDIX D. PROCUREMENT PRICE FOR MRAP VEHICLES

					CAT I		
Vehicle Awards To Date					Qty	Total Cost	Avg Unit Cost
BAE	LRIP 1	14-Feb-07	FY07	DO 2	15	$8,131,500	$542,100
FPII	LRIP 1	14-Feb-07	FY07	DO 2	65	$33,185,100	$510,540
GDLS	LRIP 2	23-Feb-07	FY07	DO 2	10	$5,295,090	$529,509
FPII	LRIP 3	23-Apr-07	FY07	DO 3	772	$343,008,092	$444,311
IMG	LRIP 4	31-May-07	FY07	DO 2	1,200	$623,073,400	$519,228
FPII	LRIP 5	19-Jun-07	FY07	DO 4	395	$187,466,210	$474,598
AH	LRIP 7	13-Jul-07	FY07	DO 2	1,154	$511,222,000	$443,000
IMG	LRIP 7	20-Jul-07	FY07	DO 4	755	$413,869,860	$548,172
GDLS	LRIP 8	7-Aug-07	FY07	DO 3	600	$335,748,600	$559,581
FPII	LRIP 8	10-Aug-07	FY07	DO 5	25	$12,763,500	$510,540
FPII	LRIP 9	18-Oct-07	FY08	DO 6	553	$245,703,983	$444,311
IMG	LRIP 9	18-Oct-07	FY08	DO 5	1,000	$537,241,000	$537,241
AH	LRIP 10	18-Dec-07	FY08	DO 3	668	$305,676,132	$457,599
FPII	LRIP 10	18-Dec-07	FY08	DO 7	178	$90,876,120	$510,540
IMG	LRIP 10	18-Dec-07	FY08	DO 6	1,500	$805,861,500	$537,241
AH	LRIP 11	14-Mar-08	FY08	DO 4	1,024	$481,835,008	$470,542
FPII	LRIP 11	14-Mar-08	FY08	DO 8	12	$6,321,792	$526,816
IMG	LRIP 11	14-Mar-08	FY08	DO 7	526	$291,038,460	$553,305
GDLS	LRIP 12a	17-Jul-08	FY08	DO 4	773	$442,841,162	$572,886
Avg Unit Cost/Awards to Date					**11,225**	**$5,681,158,509**	**$506,117**

Table 22. Procurement Price for CAT I MRAP Vehicles (FY 2007 to 2008)

					CAT II		
Vehicle Awards To Date					**Qty**	**Total Cost**	**Avg Unit Cost**
FPII SS	N/A	9-Nov-06	FY07	DO 1	100	$57,306,400	$573,064
FPII SS	N/A	5-Dec-06	FY07	DO 2	100	$57,306,400	$573,064
BAE	LRIP 1	14-Feb-07	FY07	DO 2	75	$47,235,000	$629,800
FPII	LRIP 1	14-Feb-07	FY07	DO 2	60	$34,221,840	$570,364
FPII	LRIP 3	23-Apr-07	FY07	DO 3	228	$120,867,816	$530,122
IMG	LRIP 5	18-Jun-07	FY07	DO 3	16	$8,492,976	$530,811
FPII	LRIP 5	19-Jun-07	FY07	DO 4	60	$34,221,840	$570,364
BAE	LRIP 6	28-Jun-07	FY07	DO 3	255	$122,349,000	$479,800
AH	LRIP 7	13-Jul-07	FY07	DO 2	16	$7,321,584	$457,599
FPII	LRIP 8	10-Aug-07	FY07	DO 5	100	$57,036,400	$570,364
BAE	LRIP 9	18-Oct-07	FY08	DO 5	399	$191,440,200	$479,800
FPII	LRIP 9	18-Oct-07	FY08	DO 6	247	$130,940,134	$530,122
BAE	LRIP 10	18-Dec-07	FY08	DO 6	600	$287,880,000	$479,800
FPII	LRIP 10	18-Dec-07	FY08	DO 7	180	$102,665,520	$570,364
BAE	LRIP 11	14-Mar-08	FY08	DO 7	393	$191,980,500	$488,500
FPII	LRIP 11	14-Mar-08	FY08	DO 8	6	$3,527,628	$587,938
Avg Unit Cost/Awards to Date					**2,835**	**$1,454,793,238**	**$513,155**

Table 23. Procurement Price for CAT II MRAP Vehicles (FY 2007 to 2008)

					CAT III		
Vehicle Awards To Date					**Qty**	**Total Cost**	**Avg Unit Cost**
FPII SS	N/A	9-Nov-06	FY07	DO 1	44	$30,762,116	$699,139
FPII SS	LRIP 4	30-May-07	FY07	DO 6	14	$9,787,946	$699,139
FPII SS	LRIP 11	14-Mar-08	FY08	DO 7	11	$7,690,529	$699,139
Avg Unit Cost/Awards to Date					**69**	**48,240,591**	**$699,139**

Table 24. Procurement Price for CAT III MRAP Vehicles (FY 2007 to 2008)

APPENDIX E. GOVERNMENT FURNISHED EQUIPMENT COST FOR MRAP VEHICLES

USMC

Equipment	Cost Per Vehicle
MCTAGS	$9,065
OGPK	$10,788
Drivers Vision Enhancement (DVE), A Kit (11.5K) & B Kit (11.5K ea)	$23,000
BFT Install Kit, Cables, MT2011E/F Mount	$0
BFT Keyboard Trays	$286
FBCB2/Blue Force Tracker	$16,022
Defense Advanced GPS Receiver (DAGR)	$2,131
DAGR Spares (10%)	$0
Counter IED Jammer	$88,000
HANDCRANKS	$551
AN VRC-103 UHF SATCOM Radio	$7,917
AN VRC-104 HF Radio	$3,611
AN/VRC-104 RF cable	$32
AN/VRC-110 MBR	$14,400
MT 6352 Mounting Tray	$1,252
SATCOM ON THE GO & AN/VRC 110 Cables	$555
TOCNET Vehicle Intercom System	$35,277
Power Distribution Unit (PDU)	$1,106
Metal work 585,000	$339
360 degrees Spotlight	$13,000
Headsets	$283
Vehicle Medical Kit	$1,351
GyroCam	$2,656
Integration - 2nd phase	$26,507
Total	**$258,129**

Table 25. Cost of GFE for Marine Corps (FY 2008)

Army

Equipment	Cost Per Vehicle
OGPK	$14,623
DVE A Kit	$10,431
DVE B Kit	$10,431
Vic-3	$14,623
WALK	$983
FBCB2	$24,371
CVRJ	$85,787
SINCGARS B Kit	$2,340
SINCGARS B Kit	$15,208
AN/VRC-103	$24,015
AN/VRC-104	$29,246
LRAS	$300
MTS	$136
RHINO	$4,484
TWO ITAS	$61
Integration (100/month)	$9,810
Total	**$246,848**

Table 26. Cost of GFE for Army (FY 2008)

Navy

Equipment	Cost Per Vehicle
MCTAGS	$5,380
OPGK	$11,884
FBCB2/Blue Force Tracker	$13,902
DAGR	$2,131
BFT Keyboard Trays	$287
Counter IED Jammer Chameleon for CAT I	$64,600
Counter IED Jammer Chameleon for CAT II	$18,027
AN VRC-103 UHF SATCOM Radio	$51,163
AN VRC-104 HF Radio	$11,509
MT-6352	$1,134
AN VRC-110 Multi-Band Radio	$35,712
TOCNET Vehicle Intercom System	$27,526
DVE	$22,472
Lighting, PA and Siren ECP	$5,000
TOCNET Upgrade	$696
Litters (CASEVAC)	$441
Manual Traversuring Unit (MTU)	$145
Integration	$12,250
Total	**$284,258**

Table 27. Cost of GFE for Navy (FY 2008)

Air Force

Equipment	Cost Per Vehicle
AN VRC-110	$2,475
AN VRC-111 Multiband Radio	$28,390
AN VRC-111 Installation Kit	$2,505
AN VRC-104 HF Radio w/o RT	$16,700
CREW 2.1 (IED Jammer)	$84,844
DAGR	$0
DAGR Antennae	$0
Duke (IED Jammer)	$1,122
EPLRS Radio for FBCB2	$12,076
FBCB2/BFT	$22,000
MCTAGS	$929
Manual Traversing Unit (MTU)	$57
MRC-167 PDU w/Cables	$1,300
MT-6352 Power Tray	$965
OGPK (Turret)	$14,462
PRC-117 Installation Kit	$15,030
Thermal Imager DVE	$13,026
TOCNET	$35,000
X-Wing SATCOM Antennae	$1,130
Integration	$17,780
Total	**$269,791**

Table 28. Cost of GFE for Air Force (FY 2008)

SOCOM

Equipment	Cost Per Vehicle
MBITR (PRC-148)	$14,351
MBITR Integration	$16,483
VIC-3	$10,826
FY07: C4I Support/Long Lead Items (SATCOM, ROVER III, BFT) & Components for VIC3, MBITR, ECMS and Engineering Support	$42,060
ECM System	$2,682
Gunners Protection Kit	$9,147
Kongsberg Remote Weapons Station (RWS)	$356,393
FY 08 (PROC): RWS & C4I (Hardware/Software) Upgrades	$42,643
RWS Training Devices/Instructors	$27,886
Additional Load List	$22,443
Total	**$544,914**

Table 29. Cost of GFE for SOCOM (FY 2008)

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